PAÑCASIDDHĀNTIKĀ

VARĀHA MIHIRA

T.S.K. SASTRY

K.V. SARMA

PAÑCASIDDHĀNTIKĀ

OF VARĀHAMIHIRA

WITH TRANSLATION AND NOTES

BY

T.S. KUPPANNA SASTRY

CRITICALLY EDITED

WITH INTRODUCTION AND APPENDICES

BY

K.V. SARMA

P.P.S.T. FOUNDATION
ADYAR, MADARS
1993

THE BOOK

The *Pañcasiddhāntikā* of the sixth century astronomer Varāhamihira is a major work on mathematical astronomy of early India, and is particularly significant for the fact that it provides a résumé, though uneven, of five astronomical schools, *viz.*, *Vāsiṣtha*, *Paitāmaha*, *Romaka*, *Pauliśa* and *Saura*, which flourished in India during the early centuries of the Christian era. The full texts of all these systems are now lost, which makes the *Pañcasiddhāntikā* all the more significant. All the available manuscripts of the work go back to a defective original. This makes the full and correct understanding of the work difficult and indefinitive, there being also occasional lacunae and obscure passages. These have, in many places, affected adversely the text and the translations of this work as issued earlier, by G. Thibaut and Sudhakara Dvivedi (Benares, 1889) and by O. Neugebauer and David Pingree (Copenhagen, 1970).

The present Critical edition of the *Pañcasiddhāntikā*, which makes use of all the available manuscripts of the text as also external testimony, attempts to present a much more perfect text and translation of the work. To the edition has been added an authentic translation of the work with explanatory notes in terms inclusive of modern mathematics, adumbrated by tables and diagrams. Wherever computations are involved, illustrative examples are worked out. Besides an informative and analytical General Introduction, explanatory introductions are prefixed to chapters indicating the contents and the method of approach adopted in those chapters.

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PREFACE

The *Pañcasiddhāntikā* of the sixth century astronomer Varāhamihira is a major work on mathematical astronomy of early India. The work is particularly significant for the fact that, besides providing an insight into the level of contemporary development in the discipline, it forms also a resumé, though uneven, of five astronomical schools, to wit, the *Vāsiṣṭha*, *Paitāmaha*, *Romaka*, *Pauliśa* and *Saura*, that were in vogue in India during the early centuries of the Christian era, but whose original texts have not came down to us and are lost on account of improved astronomical systems having been developed in course of time.

There have appeared two earlier editions of this cryptic technical text, the first by G. Thibaut and Sudhakar Dvivedi (Banaras, 1889) and second by O. Neugebauer and D. Pingree (Copenhagen, 1970-71). But both these editions have limitations and imperfections, even as their editors themselves have indicated in their Introductions to the said editions. The main difficulty in gaining a proper understanding, let alone producing a correct edition, of the *Pañcasiddhāntikā* has been confounded on account of all the available manuscripts having descended from a single corrupt archetype. This aspect of the matter cannot be better expressed than in the words of G. Thibaut in the Preface (p.v.) to his edition of that work. He says :

> "Imperfect and fragmentary as (the) text and (the) translation are, we may assert, at any rate, that in our endeavours to overcome the quite unusual obstacles which the corrupt and bare text of the Pañcasiddhāntikā opposes to the interpreter, we have spared no trouble. The time and thought devoted to the present volume would, I may say without exaggeration, have amply sufficed for the editing and explaining of twenty times the amount of text presenting only normal difficulties."

Hence the need for a further attempt for a better edition and interpretation of this important text on early Indian astronomy.

The present edition which is based on all the available manuscripts of the text and also external testimonia and which takes into consideration the work of interpretation attempted in the two previous editions, presents as critical and readable a text as is possible on the basis of the above-said material. To this is added a literal translation with explanatory words added as necessary. This is followed by detailed explanatory notes in terms inclusive of modern mathematics, and adumbrated with tables and diagrams. Whenever computations are involved, illustrative examples are given and worked out. There again, most of the chapters are provided with explanatory introductions indicating the general contents and method of approach of the matter contained in the chapters.

The above work has been a labour of love pursued by the late Prof. T.S. Kuppanna Sastry, formerly Professor in the Sanskrit College, Madras. A scholar in Sanskrit, a student of modern mathematics and one fully conversant with Jyotiśśāstra, Prof. Sastry was an ideal combination of Indian and Western schools of astronomy. And, as such, he was best fitted for the task of expounding a difficult text on Indian astronomy like the *Pañcasiddhāntikā*.

When Prof. Sastry passed away in 1982, he left behind his handwritten manuscript which was in different states of perfection. While the earlier chapters were in their final form, chapter XIV had been left untouched and so also were verses 35 to 55 of chapter XVIII. The later chapters, portions of which had been issued in the form of articles, were in their rough draft form.

The above-said material was placed in my hands by Dr. T.K. Balasubramanian, Scientist, Bhabha Atomic Research Centre, Bombay, Prof. Sastry's son, with the suggestion that the same might be duly processed and perfected and made pressworthy and placed before the world of scholars in printed form. As an academic associate of Prof. Sastry for nearly three decades, I accepted the challenge and set to work on it without delay. In this matter I had the cooperation of two eminent scholars in astronomy, Prof. K.S. Shukla of Lucknow and Shri. S. Hariharan of Bangalore.

Work on Prof. Sastry's manuscript was twofold. The first related to the perfection of the existing Translation and Notes and the supply of the same for the sections which were left out by Prof. Sastry. Prof. Shukla translated Ch. XIV with notes and diagrams and Shri. Hariharan supplied the Translation and Notes for the verses left out in Ch. XVIII. While the above was done at Lucknow and Bangalore, respectively, in Madras, the end chapters were put in proper form. Alongside, the entire manuscript, running to about 500 pages, was duly perfected. This revision work included also such matters as the crosschecking of entries, supply of diacritical marks to Sanskrit expressions, marking off of paragraphs, making the presentation uniform, and several other allied matters. The manuscript, revised as above, had also to be typed out and checked again. The large number of diagrams occurring in the work were also drawn to scale with the use of geometrical instruments and added at appropriate places.

The second task related to the critical editing of the textual verses. A draft press copy was prepared on the basis of the readings adopted by Prof. Sastry. Copies of all manuscripts of *Pañcasiddhāntikā* available at different repositories were procured and collated with the draft press copy. The text in the two printed editions and in the external testimonia, which had also been assembled, was collated similarly and the variants recorded. And, on the basis of the above, the final press copy of the critical text was prepared. Varied typography for the half a dozen different items of the edition was also selected to set off the same distinctly in print.

The resultant edition, provided with an Introduction and necessary Appendices including a Subject Index, is now placed before scholars. It is to be hoped that this edition of *Pañcasiddhāntikā* will contribute, in some measure, to the furtherance of the study and appraisal of early Indian mathematics and astronomy.

The publication of this volume had been made possible by the generous contribution of friends and patrons of academic studies. The Birlas made a gracious donation of Rs. 20,000/- and Dr. T.K. Balasubramanian, of Rs. 5,000/-. The Rashtriya Veda Vidya Pratishthan, New Delhi, has extended the major financial assistance in the form of purchasing copies of the book amounting to about rupees one lakh. The most profound thanks are due to the above named patrons for their kind gesture. Thanks are due to the Bhandarkar Oriental Research Institute, Poona, Oriental Institute, Baroda, and National Library, Calcutta, for their kind coöperation

by supplying copies of the manuscripts of *Pañcasiddhāntikā* available with them. For the beautiful printing and nice get-up, thanks are due to Ms. Printers Plates, one of the leading presses of Madras. The PPST Foundation, Madras, an organisation set up for the popularisation of Indian sciences, has kindly undertaken the responsibility for the distribution of this publication. Last but not least, my grateful thanks are due to Prof. K.S. Shukla and Shri. S. Hariharan, who, besides making their personal contribution to the volume, had been available for reference and advice at all stages of the work on the present edition of the *Pañcasiddhāntikā*.

Madras,
January 4, 1993

K.V. SARMA

CONTENTS

INTRODUCTION

1. Introductory

The *Pañcassiddhāntikā (PS)* of Varāhamihira (VM), (6th cent. A.D.), occupies an important place in the history of early Indian astronomy, for, herein we have been given certain aspects of five systems of Indian astronomy current during the first centuries of the Christian era. The work supplies also considerable additional material on the astronomical concepts, computational methods and instruments used during the times of the author. VM makes mention of the objectives of the work towards its commencement:

pūrvācāryamatebhyo yad yad śreṣṭham laghu sphuṭam bījam |
tat tad ihāvikalam aham rahasyam udyato vaktum || I.1 ||
Pauliśa-Romaka-Vāsiṣṭha-Saura-Paitāmahās tu pañca siddhāntāḥ || 2 ||

'Here, I shall state in full the best of the secret lore of astronomy extracted from the different schools of the ancient teachers so as to be easy and clear.

'The five *siddhānta-s*, of which this work is a compendium, are the *Pauliśa*, the *Romaka*, the *Vāsiṣṭha*, the *Saura* and the *Paitāmaha*.

Following the above statement, VM specifies also how he is intending to deal with the said five astronomical schools :

yat tat param rahasyam bhavati matir yatra tantrakārāṇām |
tad aham apahāya matsaram asmin vakṣye graham bhānoḥ ||
dik-sthiti-vimarda-karṇa-pramāṇa-velā grahāgrahāv indoḥ |
tārāgrahasaṃyogam deśāntarasādhanam cā 'smin ||
samamaṇḍala-candrodaya-yantra-cchedyāni śāṅkavacchāyā |
upakaraṇādy akṣajyā-'valambakā-' pakramādyāni || I.5-7 ||

'I shall tell in this work, avoiding all jealousy, the computation of the solar eclipse which is guarded as a great secret and in which the mind of the astronomer reels. I shall also tell the occurrence or non-occurrence of the lunar eclipse, the directions of the first and last contacts, the duration, the total phase, the 'hypotenuse' at any moment with related quantity of obscuration and time, and also the mutual conjunctions of the stars and the planets and the computation of difference in longitude as also the prime vertical, moonrise, astronomical instruments and other requirements, graphical representations, the gnomonic shadow, the sines of latitude, co-latitude and declinations and such other matters.'

While the importance of the work in the reconstruction of early Indian astronomy would be apparent from the above statement, the paucity of reliable manuscripts of the work makes the preparation of a correct edition of the work a formidable task, affecting, in its turn, a proper understanding, translation and interpretation of the work. The gravity of the problem could be gauged from what G. Thibaut has stated in the Preface to the first edition of the work (TS), issued in 1889. He says:

1. *The Pañcasiddhāntikā*, the astronomical work of Varāha Mihira. The Text edited with an original commentary in Sanskrit and an English translation, by G. Thibaut and Mm Sudhakara Dvivedi, Leipzig : Varanasi, 1889; *Rep.* Lahore, 1930; *Rep. Varanasi, 1968. (Page references made are to this reprint.)*

> "There is some reason to fear that the feeling of any one who may examine in detail this edition and translation of Varāha Mihira's astronomical work will, in the first place, be wonder at the boldness of the editors. I am fully conscious that on the imperfect materials at our disposal an edition in the strict sense of the word cannot be based, and that what we are able to offer at present deserves no other name but that of a first attempt to give a general idea of the contents of the Pañcasiddhāntikā. It would, in these circumstances, possibly have been wiser to delay an edition of the work until more correct Manuscripts have been discovered. Two considerations, however, in the end, influenced us no longer to keep back the results, however imperfect, of our long continued endeavours to restore and elucidate the text of the Pañcasiddhāntikā. In the first place, we were encouraged by the consideration that texts of purely mathematical or astronomical contents may, without great disadvantages, be submitted to a much rougher and bolder treatment than texts of other kinds. What interests us in these works is almost exclusively their matter, not either their general style or the particular words employed, and the peculiar nature of the subject often enables us to restore with nearly absolute certainty the general meaning of passages the single words of which are past trustworthy emendation. And, in the second place, we feel convinced that even from that part of the Pañcasiddhāntikā which we are able to explain more is to be learned about the early history of Sanskrit Astronomy than from any other work which has come down to our time." (p.v.).

About the manuscript material available to him and the editorial criteria adopted by him Thibaut says in his Introduction to the edition:

> "The present edition of the Pañcasiddhāntikā is founded on two Manuscripts, belonging to the Bombay Government. The text of the better one of those two Manuscripts is reproduced in the left hand columns of our edition, while the foot notes give all the more important different readings from the other Manuscript. A comparison of the traditional text with the emended one, as given in the right hand columns of the edition, will show that the former had, in many cases, to be treated with great liberty. Not unfrequently, the emended text is merely meant as an equivalent in sense of what we suppose Varāha Mihira to have aimed at expressing, while we attach no importance to the words actually employed in the emendation." (p.lx).

The *Pañcasiddhāntikā* has again been edited recently by O. Naugebauer and D. Pingree, (NP)[2]. And Pingree too observes, on the state of the manuscript material: "The present edition of the Pañcasiddhāntikā does not solve all the remaining problems connected with this text. We suspect that much will never be understood unless better manuscripts material becomes available." (Vol. I, Intro., p.19)

It, however, so happens that during the hundred years that have passed by since the publication of its first edition in 1889 no 'really' new manuscript of the work has come to light. A few manuscripts that have become available,[3] all go back to the two manuscripts used in the first edition, as shown by the commonality in them of omissions and corruptions which occur in the newly available manuscripts.

2. *The Pañcasiddhāntikā* of Varāhamihira. Pt. I. Text and Translation by D. Pingree; Pt. II. Notes by O. Neugebauer, Cobenhavn, Munksgaard, 1970.

3. For details, See below under 'Manuscript material'.

The edition of *Pañcasiddhāntikā* which is now issued is also based on the manuscripts used for the two above-said editions. The question that would naturally arise here would be: Why then is the need for another edition when no new source material is to be had? The answer is threefold:

i. First, it was felt that in reconstructing the text from the corrupt manuscripts, which alone are available, both TS and NP have subscribed to an editorial principle voiced by Thibaut when he says: "What, in the attempt to reconstitute the text of an astronomical or mathematical work, has chiefly to be kept in view, is of course to arrive at rules which are capable of being proved mathematically. This consideration has, in more than one place, led us to introduce changes even where such appeared hardly to be required by the external form of the traditional text." (Introduction, p.lxi), And, this they have done to an extent which seems to be hardly justified in editing a classical text. Then again, such emendations are often inserted without specific indication, especially in the edited text of NP, with the result that the reader takes the emended text as the 'real' manuscript text. The translation and interpretations that follow are, primarily, based on the emended text and not on the 'real' text. In fact, an editorial principle which has to be applied with the utmost caution and in as limited a manner as possible, seems to have been used rather extensively.

In the present edition of *Pañcasiddhāntikā*, the principle of *sthitasya gatiś cintanīyā*, 'justification of the extant reading should be thought of', has been primarily adhered to, alongside the correction of the copyist's errors by visualising the psychology of the scribe who is illiterate with reference both to the language and the subject of the text. 'Real' emendations have been comparatively small and far between. In all cases, however, when changes had to be made to the manuscripts readings, they have been specifically indicated by their being placed within curved brackets in the case of scribal errors and in square brackets in the case of editorial supplementation. And, whenever there has been an emendation, the reasons for suggesting the emendation have been given in the Notes that follow each verse.

ii. Secondly, in a number of places, TS nor NP do not seem to have caught the correct import of the text and this has affected their Translation and Notes. All these have been attempted to be rectified. In many places, the untenability of the TS and NP readings, translations and notes have also been pointed out.

iii. Thirdly, and what is most important, special effort has been made to digest the textual verses fully, and offer, in the case of knotty places and apparently vague passages, detailed interpretations and elucidations, adumbrated with tables and illustrations. Moreover, a number of examples have also been worked out to illustrate the rules enunciated by Varāhamihira.

Under the circumstances, it is to be hoped that the present publication will form another step towards understanding and evaluating the principles and practices of early Indian astronomy.

2. Source Material

A-B. The available manuscripts of *Pañcasiddhāntikā*, of which five have been collated for preparing the present edition, fall into two recensions which have been designated as A and B. Common corruptions and omissions indicate that even these two recensions go back to a common original which too should have been far from perfect in the matter of accuracy. The technical nature of the work, brizzling with unusual terminology, have made the scribes commit all types of imaginable errors except in the case of well-known words and expressions. These errors include, as a reference to the footnotes recorded in the edition would show, wrong spellings, erratic *sandhi*-s and splitting

of words, omission of vowel signs, verses made to stop short in the middle or to run into another, numbering of verses in the wrong places and so on. In several cases some of these corruptions are common to all the manuscripts, confirming that these errors have to be traced back to a common archetype of both the recensions.

The said five manuscripts have been designated A1, A2 and B1, B2, B3, according to the two recensions and relative reliability of the manuscripts. All the manuscripts are in paper, written in Devanagari script.

A_1. Ms. No. 338/1879-80 of the Bhandarkar Oriental Research Institute, Pune, described in *A Catalogue of Collections of Mss. deposited in the Deccan College* by S.R. Bhandarkar (Bombay, 1888), p. 143. It has 22 folios with 11 lines per page. It is complete and has been copied at Stambhatīrtha (modern Cambay in Gujarat) in Sam. 1673, Śaka 1538 (AD. 1616), by Śaṅkara son of Govinda. This manuscript is the 'better of the two manuscripts' used in the TS. edition of the *PS*. The manuscript is far from perfect and exhibits numerous scribal errors and some transpositions, but it is definitely better than the B manuscripts.

A_2. Ms. No. 49, currently preserved in the National Library, Calcutta, but it originally belonged to the erstwhile Imperial Library, Calcutta. It is in 24 folios with 9 lines a page. It is incomplete and extends to a portion of XVIII. 90 d. The writing is very readable but is very much error-ridden. The readings are closely associated to A_1.

Pingree suspects that it "agrees almost entirely with A (our A_1) of which it is most probably a copy." (see his edition of *PS*, Introduction, p. 20). This cannot be a copy of A_1 for the reason that there occur differences between the two, for which see I. 3c, 7d, 10a, 12a and a number of other contexts.

Pingree doubts also that A_2 is "perhaps the copy utilized by Thibaut and Dvivedin" (Introduction, p.20). This goes against Thibaut's statement that his "edition of *PS* is founded on two Manuscripts belonging to the Bombay Government" (T's Introduction, p. LX). It is also to be noted that while A_1 is complete, A_2 is incomplete. It is again to be noted that minor over-writings and corrections above the lines occur in A_2 at several places obviously having been added by a modern user of the manuscript. These latter, being modern, have not been noted as variants in the footnotes to the present edition.

B_1. Ms. No. 37/1874-75 of the Bhandarkar Ori. Res. Inst., Pune, described in *A Catalogue of Collections of Mss. deposited in the Deccan College* (Bombay, 1888). Copied in modern "Universal foolscap" paper, with a title page in Devanagari reading "number 37-Satra 1872 [A.D.] Pañcasiddhāntikā, patrāṇi 49-15-1930", it is in 49 pages, with 15 to 17 lines a page. This is the second of the two manuscripts used by TS, from which they have documented only some of the variants, as recorded in the footnotes of their edition.

Pingree states (Intro., p.20), that in the edition he has documented only those variants recorded by TS in their footnotes. In the present edition, however, the manuscript has been fully collated and all the variants therein recorded. This manuscript carries, through its entire length, corrections, obviously made by Thibaut.

B_2. Ms. No. 64 of the National Library, Calcutta. It contains 108 pages numbered 7 to 114, and is incomplete, commencing only from I.22, the previous verses having been written on the folios 1-6, now lost. The manuscript is shapely and the writing readable, but the matter contained is extremely

corrupt. The numbering of the verses is also erratic. Several verses are broken in their middle and verse numbers are interposed. At times the last line of a verse is continued with the beginning letters of the next verse, entailing at times, the beginnings and ends being half-words. (see III. 1 and 2). The manuscript seems to be the handiwork of a good-handed scribe from a highly corrupt original. Corrections by a modern hand in lighter ink is seen at places.

Pingree suspects that "this manuscript seems to be a copy of B – perhaps that used by Thibaut and Dvivedin." (Introduction, p.20).

B_3. Ms. No. 7165 of the Oriental Institute, Baroda. This manuscript in 33 folios contains the complete work. A post-colophonic statement says that it was copied in Saṁ,. 1928/śaka 1793 (A.D. 1872) by Uttamarāma Durlabharāma, a resident of Amadāvāda (Ahmedabad). The writing is readable but corrupt readings persist. Verse numbers are written for the first chapter, but not for the later chapters. Numbers expressed in the verses are written also in digits in many places.

A few more manuscripts of *Pañcasiddhāntikā* are known to exist (or to have existed) but could not be used for the present edition. They are :

1. Ms. No. 288 of the Bombay University. This is at present missing in the Library. Pingree has used this manuscript. In 32 folios it contains the full text of *PS*. It was copied in Saṁ. 1928, corresponding to AD. 1871, by Nāthurāma Pārika.

2. Ms. No. 6288 of the India Office, London, (Buhler 268) described in the *A Catalogue of Skt. and Pkt. Mss. in the India Office Library*, vol. II by A.B. Keith. This is a copy of our Ms. A_1, copied in Saṁ 1936, Śaka 1802 (A.D. 1879). We have not used it nor has Pingree.

About still other manuscripts, Pingree states : "Besides these seven manuscripts, there existed in 1890 the manuscript belonging to J.B. Modak of Thāṇā which was copied from B (our B_1), and we know of a manuscript (no. 6674) of the Pañcasiddhāntikā in the Ānandāśrama in Poona. The manuscripts, recorded as the property of Sjt. Pushpachandra Sarma Daloi of Helach in Assam and of the Arsha Library in Vijayanagara (no. 506), probably contain the *Bhāsvatī* of Śatānanda, which is sometimes confused with our text." (Introduction, p. 21).

C. The emended text of Thibaut-Sudhakara Dvivedi, as printed in the right hand columns of their edition. On this Thibaut says (Introduction, pp. lx-lxi):

> "The present edition of the Pañcasiddhāntikā is founded on two manuscripts belonging to the Bombay Government. The text of the better one of these two Manuscripts is reproduced in the left hand columns of our edition, while the foot notes give all the more important different readings from the other Manuscript... the emended one as given in the right hand columns of the edition.
>
> "What, in the attempt to reconstruct the text of an astronomical or mathematical work, has chiefly to be kept in view, is of course, to arrive at rules which are capable of being proved mathematically. This consideration has, in more than one place, led us to introduce changes even where such appeared hardly to be required by the external form of the traditional text."

Notwithstanding the wild emendations which Thibaut-Sudhakar Dvivedi have made, at times, their emended readings have been recorded as C in the footnotes of the present edition.

D. The edition, Translation and Notes of *TS* by O. Neugebauer and D. Pingree, (2 vols., Kopenhagen, 1970). Pingree edits and translates the *PS*, while Neugebauer offers the Notes. All

our manuscripts are used in this edition too. Herein occur a number of emendations which are sometimes put within brackets, but sometimes without brackets. Often the emendations are wilder than those of Thibaut-Sudhakar Dvivedi.

E. External testimonia. About 125 *Pañcasiddhāntikā* verses have been identified as quoted in later texts, the largest number thereof, 117 being in the commentary of Utpala of Kashmir (A.D. 966) on the Bṛhatsamhitā of Varāhamihira. Other authors who quote from the *PS* are Pṛthūdakasvāmin (A.D. 854), Makkibhaṭṭa (14th cent.), Parameśvara of Kerala (1360-1460), Nīlakaṇṭha Somayāji, (b. 1443), again of Kerala, and Sūryadevayajvan (b. 1191) of Tamilnadu, in South India. These *PS* quotations are taken as External Testimonia and the variants found in such readings have been noticed in the footnotes with 'E' prefixed to the abbreviations of authors/works which quote the verses. These sources are :

E. Jy. *Jyotirmīmāṁsā* of Nīlakaṇṭha Somayāji.
E.M. Makkibhaṭṭa's Com. on the *Siddhāntaśekhara* of Śrīpati.
E.N. Nīlakaṇṭha Somayāji's Bhāṣya on the *Āryabhaṭīya.*
E.Pa. Parameśvara's com. on the *Āryabhaṭīya.*
E.Pr. Pṛthūdakasvāmin's com. on the *Brāhmasphuṭasiddhānta* of Brahmagupta.
E.S. Sūryadevayajvan's com. on the *Āryabhaṭīya.*
E.U. Utpala's com. on the *Bṛhatsaṁhitā* of Varāhamihira.

Pingree has adopted this method of referring to external testimonia, and we have followed him in the matter. In fact, we have been much benefitted by his identifications and our labour relates only to texts which have not been noticed by him.

On the provenance of *PS*, Pingree states that :

> "So far there is no indisputable evidence that the Pañcasiddhāntikā was known outside of an area roughly corresponding to the modern states of Madhya Pradesh, Gujarat, Rajasthan, the Punjab, Kashmir, and West Pakistan.
>
> "However, some verses from the text are quoted by fifteenth century Kerala astronomers of the dṛggaṇita school in their commentaries on the Āryabhaṭīya. Thus Parameśvara (c. 1380-1460) cites a verse, and Nīlakaṇṭha (b. 1443) several others. It is noteworthy that all four verses that they quote are also found in Utpala's commentary on the Bṛhatsṁhitā, which was known in Kerala; it is not proved, then that they had a copy of the Pañcasiddhāntikā." (Introduction p. 17).

Pingree's assertion as above is not correct for the reason that Kerala and South Indian astronomers quote not only the said four verses occurring in Utpala's commentary, but five more *PS* verses which do not occur in Utpala's commentary, they being *PS*, I.3, 4 by Nīlakaṇṭha in his *Jyotirmīmāmsā*, the verses *saṅkhyā tu teṣām* and *yāny ataḥ prati* again by Nīlakaṇṭha in his *Āryabhaṭīya-bhāṣya* IV.10 and *PS* XIII.36 by Sūryadevayajvan in his *Āryabhaṭīyavyākhyā.* (See below App. II: Index of PS verses quoted by later astronomers). This would mean that *PS* should have been prevalent in South India also.

Recording of Variant readings

Textual variants recorded in footnotes in the present edition are restricted to be above-said material listed under A, B, C, D and E. Some of the *PS* verses have, indeed been studied by scholars but emendations and variants occurring in these studies have not been recorded here mainly for the

reason that they have mostly been documented by Pingree in his edition of the *PS* and so can be referred to therefrom.[1]

3. Presentation of the Text

While the generally accepted conventions of critical editing of Indic texts are duly followed in the present edition, attention might be drawn to certain methodologies which are stressed herein, in view of the technical nature of the text, the defective nature of the manuscripts and the tentativeness of many of the emendations and textual changes effected in the two earlier editions.

i. On account of the inadequacies of the copyists of the parent manuscripts and also due to deficiencies in the parent manuscripts themselves, some emendations have to be done in the edited text. However special care has been taken in this edition to indicate such emendations by placing them within curved brackets; square brackets are used to enclose fillings of apparent omissions or newly suggested readings. Doubtful suggestions are marked by an interrogation mark.

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1. Studies mentioned in this footnote have mostly been identified by Pingree and on pages 18-19 of his edition of *PS* and variants.

i. G. Thibaut, 'Notes from Varāha Mihira's Pañcasiddhāntikā', *Jl. of Asiatic Society of Bengal*, 53 (1884) 259-93.

ii. S.B. Dikshit, 'The Original Sūrya-siddhānta', *Indian Antiquary*, 19 (1890) 45-54.

iii. S.B. Dikshit, 'The Romaka Siddhānta', *Indian Antiquary*, 19 (1890), 133-42.

iv. S.B. Dikshit, 'The Pañcasiddhāntikā', *Indian Antiquary*, 19 (1890) 439-40.

v. J. Burgess, 'The Romaka Siddhānta', *Indian Antiquary*, 19 (1890) 284-85.

vi. J. Burgess, 'The sines and arcs in the Pañcasiddhāntikā', *Indian Antiquary*, 20 (1891) 228.

vii. M.P. Kharegat, 'On the interpretation of certain passages in the Pañcha Siddhāntikā of Varāhamihira, an old historical work' *Jl. of the Bombay Branch of the Royal Asiatic Society*, 19 (1895-97) 109-41.

viii. K.S. Shukla, 'On three stanzas from Pañcasiddhāntikā,' *Gaṇita*, 5 (1954) 129-36.

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ix. 'The Vāsiṣṭha Sun and Moon in Varāhamihira's Pañcasiddhāntikā', *Jl. of Or. Research*, Madras, 25 (1955-56) 19-41.

x. 'Some misinterpretations and omissions in Thibaut and Sudhakara Dvivedi in the *PS* of VM', *Vishvèshvaranand Indological Journal*, 11 (1973) 107-18.

xi. 'The epoch of the Romaka Siddhānta in the *PS* and the epoch longitudes of the Sun and Moon the Vāsiṣṭha Siddhānta', *Indian Jl. of Hist. of Science*, 13 (1978) 151-58.

xii. 'The Vāsiṣṭha-Pauliśa Venus in the *PS* of VM', *Collected Papers of T.S. Kuppanna Sastry*, Tirupati, 1989, pp. 141-47.

xiii. 'The Vāsiṣṭha-Pauliśa Jupiter and Saturn in the *PS*', *Collected Papers*, pp. 148-68.

xiv. 'The Vāsiṣṭha-Pauliśa Mars in the *PS* of VM', *Collected Papers*, pp. 169-87.

xv. 'The epoch-constants of the Vāsiṣṭha-Pauliśa star-planets', *Collected Papers*, pp. 201-5.

xvi. 'Saurasiddhānta of *PS* : Planetary constants and computation', *Collected Papers*, pp. 206-40.

xvii. 'Pañcasiddhāntikā XVIII. 68-81 : An interpolation', *Collected Papers*, pp. 241-54.

ii. Thibaut and Dvivedi who print their emended text in the right hand column of their edition do not specifically indicate their emendations and one has to identify the emendations oneself. Pingree indicates his emendations in many places by angular brackets but in many other places prints the emended text without any indication. In the present edition, all their emendations are identified and noticed in the footnotes denoting them by the sigla C and D. When these emendations are accepted in the present edition also, they are not separately marked as above. This procedure is expected to enable the comparison between the emendations of TS and NP and those made in this edition and evaluate the merit and appropriateness between the two. In fact, it is felt that many of the emendations of TS and NP, especially of the latter, are often far-fetched, ungrammatical, offending the metre or failing to give a cogent sense. See, for example, the TS/NP emendations in I.23; IX.5; XI.2, 4, 5; XII.5a, 5d; XIII.38d, 41d: XVII.1, 12; XVIII.2d, 3, 19, 24, 25.

iii. In order that a discernıng student of the text shall have before him, in full, what occurs in the several manuscripts, an attempt has been made to record all variants, right or wrong. This has been done for three reasons : (a) Correct forms of corrupt passages can be visualized only if all the readings, as found in the manuscripts, are before one's eyes; (b) Then alone would it be possible for an editor to vindicate the emendations suggested by him; (c) The corrupt and apparently meaningless readings in the manuscripts which the editor could not correct or has wrongly emended can be corrected or better emendations suggested by other scholars if all the variants are given.

However, obvious errors of a purely scribal nature, like separate words written jointly, using *anusvāra* for *anunāsika* and vice versa, using double consonants for single consonants and vice versa, giving the benefit of doubt for a letter that could be read rightly or wrongly, have been corrected silently and not noticed in the footnotes.

4. Translation

The translation provided in the edition is as literal as possible without sacrificing readability and not going against the English idiom. Elucidatory expressions and words which are understood in the context are added within brackets, the ultimate aim being to make the matter dealt with clear and fully understood. Topical headings have been provided to verses or groups of verses with the same objective, again, towards the above-said objective.

5. Notes

The notes added are generally detailed and self-contained. There again, they seek to elucidate the verses and the underlying ideas, primarily from the Indian standpoint. Tables and geometrical diagrams are provided wherever warranted. Quite often, the need for the emendations suggested in the text is explained. The emendations made by TS and NP are also examined and observations offered. An aspect of the Notes which deserves special mention is the addition of self-suggested mathematical or astronomical problems and working them out according to methods enunciated in the verses, and also by employing modern methods. Introductions are prefixed for several chapters, towards setting out the significance of the contents of the respective chapters.

6. Division of Pañcasiddhāntikā

The colophons of the several Sections of *PS*, as found in the manuscripts, which all go back to a defective archetype, are uneven. Some of the colophons merely mention the topic treated in the respective sections but some others designate the sections as *adhyāya-s* (chapters) and also indicate the numbers thereof. The several colophons read :

1. Karaṇâvatāraḥ
2. Nakṣatrādicchedaḥ
3. Iti Pauliśasiddhāntaḥ
4. Iti Karaṇādhyāyaś caturthaḥ
5. Iti Śaśidarśanam
6. Candragrahaṇe ṣaṣṭhodhyāyaḥ
7. Pauliśasiddhānte ravigrahaṇam
8. Iti Romakasiddhānte 'rkagrahaṇam aṣṭamo 'dhyāyaḥ
9. Iti Sūryasiddhānte 'rkagrahaṇam navamo 'dhyāyaḥ
10. Candragrahaṇam daśamo 'dhyāyaḥ
11. A(nu)varṇanam ekādaśo 'dhyāyaḥ
12. Iti Paitāmahasiddhānte dvādaśo 'dhyāyaḥ
13. Trailokyadarśanam nāma trayodaśo 'dhyāyaḥ
14. Iti Chedyakayantrāṇi caturdaśo 'dhyāyaḥ
15. Jyotiṣopaniṣat pañcadaśo 'dhyāyaḥ
16. Sūryasiddhānte madhyagatiḥ
17. Tārāgrahasphuṭīkaraṇam ṣoḍaśo (? saptadaśo) 'dhyāyaḥ
18. Pauliśasiddhānte tārāgrahāḥ

However, whether there be full chapter headings and chapter numbers or there be only the mention of the topics in the colophons, the commencement of a new subject helps to ascertain the beginnings of the chapters. The omission of the specification of the chapter headings and numbers has to be ascribed to the imperfections in the original archetype.

This helps us to correct Pingree's edition where Chs. XVI and XVII are taken as a single chapter, which he numbers as XVI. Now, after eleven verses, here, there occurs the colophon *'Sūryasiddhānte madhyagatiḥ'*, which is the subject of those eleven verses. After still another fourteen verses occurs in the colophon *'Tārāgrahasphuṭīkaraṇam ṣoḍaśo 'dhyāyaḥ'*, and an entirely different subject is treated in those fourteen verses. Ignoring the radical difference in the subjects dealt with in the two sets of verses and the colophon after the first set of verses and guided merely by the colophon at the end of the second set of verses, Pingree combines the two sets of verses, 11 plus 14 = 25, to constitute ch. XVI and takes ch. XVIII of *TS* and of the present edition as ch. XVII.

7. Chapter XVIII of Pañcasiddhāntikā

The theme of Ch. XVIII is the heliacal rising and setting of the star-planets according to the Vāsiṣṭha and Pauliśa schools. Venus, Jupiter, Saturn, Mars and Mercury are treated, in that order, in verses 1-56, and certain allied matters in verses 57-60. In verse 61 the author states that he, Varāhamihira, hailing from Avanti, has composed the *PS* for the benefit of students. In the next verse, 62, he asks astronomers dissatisfied with Pradyumna and Vijayanandi, to resort to his work. Having thus completed his treatise, couched entirely in the Āryā metre, following a convention, adopted by Sanskrit writers, of concluding works by a closing colophonic verse couched in a different metre, VM breaks into a different metre, the Vasantatilakā, for the purpose :

āvantyakaḥ samāsāc chiṣyahitārtham sphuṭāṅkasamam |
cakre Varāhamihiras tārāgrahakārikātantram || 61 ||

Pradyumna-bhūmitanaye jīve saure 'tha Vijayanandikṛte |
budhe ca bhagnotsāhaḥ sphuṭam idam karaṇam bhajatām || 62 ||

dṛṣṭam Varāhamihireṇa sukhaprabodham |
... ... || 63 ||

The manuscripts are defective here, omitting the next three lines of the concluding verse, some exhibiting also a gap.

In continuation of the above, the manuscripts commence another short work with a *maṅgala-śloka* ('verse of salutation') and then a second verse expressing a *pratijñā* ('resolve') to compose a 'better work' by 'Varāhamihira himself.'

prastāve 'pi na doṣān jānann api vakti yaḥ parokṣasya |
prathayati guṇāṁś ca tasmai sujanāya namaḥ parahitāya ||

aṣṭādaśabhir baddhāny ā tārāgraham etad āryābhiḥ |
varam iti Varāhamihiro dadāti nirmatsaraḥ karaṇam ||

These verses end abruptly without any closing colophonic verse, as might be expected.

Not taking into consideration the fact that VM had closed the *PS most formally* with all attendant paraphernalia, with verse 63, both TS and NP treat this short work, as the *concluding part of Pañcasiddhāntikā* and as a work of *Varāhamihira himself*, and translate it and explain it as such. It is not noticed by TS and NP that computation according to these verses can give only rough results since the equation of the centre has been dispensed with, which makes them valueless. Further, there are mistakes in the computation of Venus and Mercury, which one cannot expect to be committed by VM.

The prose colophon 'Pauliśasiddhānte tārāgrahāḥ evam' ('Thus the star-planets of the Pauliśasiddhānta') does not have any reality behind it since the computations therefrom do not accord with those of the Pauliśasiddhānta elucidated earlier. These points have been discussed in detail in the Notes, below, to these verses. Obviously, these verses are apocryphal and are the handiwork of an inferior astronomer who has ascribed them to VM. For this reason, in the present edition, *Pañcasiddhāntikā* is formally closed with verse 63 and the verses following given as a *prakṣepa* (interpolation) by someone else who has moreover blacked out in the original archetype the three lines in verse 63, being the concluding verse of *PS*.

8. The Five Siddhāntas in PS : Their Distribution

It had been mentioned earlier that VM's treatment of the five siddhāntās in the *PS* are uneven. It is not that each Siddhāntā is taken up one by one and a résumé of the same given fully or systematically. Select topics are taken up, apparently arbitrarily, and are dealt with individually or jointly when the enunciations of two schools are similar. Alongside, chapters are devoted also to general astronomical topics which are applicable to all the schools. The assortment of the treatment of the subjects in the several chapters are as indicated below.

9. Content Analysis of the Pañcasiddhāntikā

Ch.I. 1-7	General	Introduction
8-10	Romaka	Days from epoch *(Ahargaṇa)*
11-13	Pàuliśa	Days from epoch *(Ahargaṇa)*
14-16	Saura-Romaka	Yugà of Sun and Moon, Lords of the year, month, and horā.

Ch.I. 17-25	Romaka	Lords of the days of the month
Ch.II 1-13	Vāsiṣṭha	
1	"	True Sun (Ravi-sphuṭa)
2-6	"	True Moon (Candra-sphuṭa)
7	"	Nakṣatra computation
7	"	Tithi computation
8	"	Day-time (Aharmāna)
9-10	"	Gnomonic shadow (Śaṅkucchāyā)
11-13	"	Lagna
Ch.III 1-37	Pauliśa	
1-3	"	True Sun (Ravi-sphuṭa)
4	"	True motion of Moon (Candragati)
5	"	Equation of the centre (Mandaphala)
6-9	"	Sense obscure
10	"	Cāra
11-12	"	Day-time (Aharmāna)
13-14	"	Deśāntara
15	"	Local time (Iṣṭadeśakāla)
16	"	Nakṣatra computation
17	"	Sun's daily motion (Ravi-gati)
18-19	"	Karaṇa-s
20-22	"	Vyatīpāta and Vaidhṛti
23-24	"	Ṣaḍaśīti-kāla
25	"	Solstices (Ayana)
26	"	Saṅkrānti-kāla
27	"	Tridinaspṛk-yoga
28-29	"	Rāhu (Node)
30-31	"	Moon's latitude (Candra-vikṣepa)
32	"	Bhadraviṣṇu, defect in
33	"	Pādāditya, defect in
34-35	"	Romaka, defect in
36-37	General	Astronomy, importance of
Ch.IV 1-58	General	Problems of Time, Space and Direction (Tripraśna)
1-15	"	Table of R sines (Jyāḥ)
16-18	"	Declination of Sun and Moon (Krānti)
19-22	"	Gnomonic shadow and derivatives (śaṅkucchāyā)
23-25	"	Sine colatitude and Day-diameter (Lambajyā and Dinamāna)
26-28	"	Cara and derivatives

Ch.IV. 29-30	"	Rt. ascensional difference (Laṅkodaya-rāśimāna)
31-34	"	Rising of signs (Rāśyudaya)
35-36	"	Gnomonic shadow (Śaṅkucchāyā)
37-38	"	Astronomer's qualifications
39-40	"	Sine amplitude (Agrā)
41-49	"	Gnomonic shadow at required time (Iṣṭacchāyā)
50-51	"	Moon's shadow (Candracchāyā)
52-54	"	Directions from shadow (Diksādhana)
55-58	"	Sun from gnomonic shadow (chāyātaḥ raviḥ)
Ch.V 1-10	Pauliśa	Moon's horns (Candraśṛṅgonnati)
Ch.VI 1-14	Vāsiṣṭha and Pauliśa	Lunar eclipse (Candragrahaṇam)
Ch.VII 1-6	Pauliśa	Solar eclipse (Ravi-grahaṇa)
Ch.VIII 1-18	Romaka	Solar Eclipse (Ravi-grahaṇa)
Ch.IX 1-27	Saura	Solar eclipse (Ravi-grahaṇa)
Ch.X 1-7	Saura	Lunar eclipse (Candra-grahaṇa)
Ch. XI 1-6	General	Eclipse diagram (Grahaṇaparilekhā)
Ch.XII 1-6	Paitāmaha	
1-2	"	Days from epoch (Ahargaṇa)
3-4	"	Tithi, Nakṣatra etc.
4	"	Vyatīpāta
5	"	Day-time (Aharmāna)
Ch.XIII 1-42	General	Situation of ther worlds (Trailokyasaṁsthānam)
Ch.XIV 1-41	General	Astronomical instruments (Chedyaka-yantrāṇi)
Ch.XV 1-29	General	Jyotiṣopaniṣat
Ch.XVI 1-11	Saura	Mean planets
1-9	"	Mean planets (Graha-madhya)
10-11	"	Bīja correction by VM

Ch. XVII. 1-14	Saura	True planets
1-11a	"	True planets (Graha-sphuṭa)
11b	"	Retrograde motion (Vakragati)
12	"	Heliacal rising (Grahāstodaya)
13-14	"	Planetary latitudes (Graha-vikṣepa)
Ch.XVIII 1-60	Vāsiṣṭha-Pauliśa	Heliacal rising and setting of planets (Grahāstodaya)
1-5	"	Venus (Śukra)
6-13	"	Jupiter (Guru)
14-20	"	Saturn (Śani)
21-35	"	Mars (Kuja)
36-56	"	Mercury (Budha)
57-60	"	Hints
61-63	General	Conclusion of PS
64-81	Spurious Supplement	True planets
64-66	"	Introduction
67-69	"	True Mars
70-72	"	True Mercury
73-75	"	True Jupiter
76-78	"	True Venus
79-81	"	True Saturn

10. Depiction of the Siddhāntas in PS

The above Content Analysis of the PS would enable the identification of the extent of selective depiction of the different siddhāntas by VM in the work, as shown below.

PAULIŚA-SIDDHĀNTA

Ahargaṇa	I.11-13
Nakṣatra	III.16
Mandaphala	III.5
Ravigati	III.17
Raviphuṭa	III.1-3
Candra-sphuṭa	III.4
Ayana	III.25
Saṅkrānti	III.26
Tridinaspṛkyoga	III.27
Desāntara	III.13-14
Cara	III.10
Aharmāna	III.11-12
Iṣṭadeśakāla	III.15
Karaṇa	III.18-19
Vyatīpāta	III.20-22
Vaidhṛti	III.20-22
Ṣaḍaśītikāla	III.23-24
Candra-vikṣepa	III.30-31
Rāhu	III.28-29
Candra-grahaṇa	VI.1-14
Ravi-grahaṇa	VII.1-6
Candraśṛṅgonnati	V.1-10
Grahāstodaya	XVIII.1-60

ROMAKA-SIDDHAÑTA

Ahargaṇa	I.8-10
Yuga	I.14-16
Lord of the year	I.17-18, 21
Lord of the month	I.19, 21
Lord of the Horā	I.20, 21
Lord of the Days	I.23-25
Ravi-grahaṇa	VIII.1-18

SAURA-SIDDHAÑTA

Yuga	I.14-16
Lord of the year	I.17-18, 21
Lord of the month	I.19, 21
Lord of the Horā	I.20, 21
Graha-madhya	XVI.1-11
Graha-sphuṭa	XVII.1-11
Graha-vikṣepa	XVII.13-14
Candra-grahaṇa	X.1-7
Ravi-grahaṇa	IX.1-27
Grahāstodaya	XVII.11-12

VĀSIṢṬHA-SIDDHĀNTA

Ravi-sphuṭa	II.1
Candra-sphuṭa	II.2-6
Nakṣatra	II.7
Tithi	II.7
Aharmāna	II.8
Śaṅkucchāyā	II.9-10
Lagna	II.11-13
Candra-grahaṇa	VI.1-14
Grahāstodaya	XVIII.1-60

PAITĀMAHA-SIDDHĀNTA

Ahargaṇa	XII.1-2
Nakṣatra	XII.3
Tithi	XII.3
Vyatīpāta	XII.4
Aharmāna	XII.5

With regard to the Chapters and verses not included in the above table, some, like chapters XI to XV, and several verses, are of a general nature, applicable to all the siddhāntas and in the case of the others it is difficult to identify positively the siddhāntas to which they pertain.

11. Comparative Study of the Siddhāntas

It can be seen from the above Table that several of the topics selected by VM from the different siddhāntas for depiction in the *PS* are common. This should enable a comparative study of the common topics, the more important of which are noticed in the Table below.

In this connection it is necessary to point out, an erroneous view current, to the effect, that the *Pauliśa siddhānta* is accurate, the *Romaka* is equally accurate, the *Saura* is still more accurate and that the *Vāsiṣṭha* and *Paitāmaha* highly inaccurate. This view has been brought into vogue through two unwarranted emendations introduced by TS and NP into the text of the following verse in the *PS*:

Pauliśatithis sphuṭo 'sau tasyāsannas tu Romaka-proktaḥ |
spaṣṭataraḥ sāvitraḥ pariśeṣau dūravibhraṣṭau || *PS. I.4*

'The *tithi* resulting from Pauliśa is tolerably accurate and that of the Romaka approximate to that. The *tithi* of the Saura is very accurate. But that of the remaining two (viz., the Vāsiṣṭha and the Paitāmaha) have slipped far away (from the real).'

Here VM speaks only about the *tithi*, (lunar day), as computed during his time according to the different siddhāntas; He is not making a relative estimate of the siddhāntas as such or in respect of the various other computations. As elucidated in the Note to this verse in the body of this book (p.5):

"The five *Siddhāntas* are compared here with reference to their *tithi alone* because that is the chief of the five *aṅgas, viz., tithi, vāra, nakṣatra, yoga* and *karaṇa*; that is most useful not only for religous purposes but also for civil purposes; that is independent of the origin of reference in the ecliptic and can be examined for correctness by observation of eclipses and heliacal rising; and that is used in finding the days from Epoch, the *sine qua non* of all astronomical computation.

"This being the case, the change of *tithi* into *kṛta* by the late Dr. G. Thibaut and M.M. Sudhakara Dvivedi (TS for short), especially when the manuscripts read only *tithi* or *titha*, is unwarranted, to say the least. Doing this, they have condemned the *Vāsiṣṭha Siddhānta* beyond

the author's•intention and become blind to its merits and peculiarities, which otherwise they could have easily seen. Equally off the mark is the emendation of *tithi* into *stvatha* by Neugebauer and Pingree (NP for short). See below, Explanatory Notes, for the real reason for this 'slipping away from the real'."

On this subject might be advantageiously referred to the section 'The place of the Vāsiṣṭha in the history of Hindu astronomy' in T.S.K. Sastry's paper 'The Vāsiṣṭha Sun and Moon' in the *Jl. of Or. Research*, Madras, 25 (1955-56) 19-41, reprinted in his *Collected Papers on Jyotiṣa* (Tirupati, 1989, pp.1-28)

Table of Common topics

Ahargaṇa	
Pauliśa	I.11-13
Romaka	I.8-10
Paitāmaha	XII.1-2
Naksatra-Tithi	
Pauliśa	III.16
Vāsiṣṭha	II.7
Ravi-sphuṭa	
Pauliśa	III.1-3
Vāsiṣṭha	II.1
Candra-sphuṭa	
Pauliśa	III.4
Vāsiṣṭha	II.2-6
Aharmāna	
Pauliśa	III.11-12
Vāsiṣṭha	II.8
Paitāmaha	XII.5
Vyatīpāta-Vaidhṛti	
Pauliśa	III.20-22
Paitāmaha	XII.4
Candra-grahaṇa	
Vāsiṣṭha-Pauliśa	VI.1-14
Saura	X.1-7
Ravi-grahaṇa	
Pauliśa	VII.1-6
Romaka	VIII.1-18
Saura	IX.1-27
Grahāstodaya	
Vāsiṣṭha-Pauliśa	XVIII.1-60
Saura	XVII.11-12

12. Varāhamihira : His Life and Works

One of the foremost early Indian astronomer and astrologer, Varāhamihira belongs to the sixth century A.D. In the *Pañcasiddhāntikā* (I.8) he takes the cut-off date or epoch for computations using the *Pauliśa Siddhānta* as Śaka 427, which corresponds to A.D. 505. Since the practice in Indian astronomical manuals (*Karaṇa-grantha-s*) is to take a contemporary date, as near to the composition of work, answering to certain specifications, as the cut-off date, it is reasonable to presume that *PS* was composed some time after A.D. 505. Regarding his demise there is a statement by Āmarāja in his commentary on Brahmagupta's *Brāhmasphuṭasiddhānta*, which reads : *navādhika-pañcasaṁkhyā-śake Varāhamihirācāryo divam gataḥ.* "In śaka 509 Varāhamihira attained to the heavens.' This would mean that VM passed away in A.D. 587. This date is corroborated by VM's mention in *PS* XV.10, of Āryabhaṭa who composed his *Āryabhaṭīya* in A.D. 499, which work should have become well known by the time that VM composed his *PS*.

Personal details about VM are forthcoming from his own writings as also from those of others. Towards the close of his *Bṛhajjātaka*, VM says:

Ādityadāsa-tanayas tadavāptabodhaḥ
Kāpittakaḥ savitṛlabdhavaraprasādaḥ |
Avantiko munimatāny avalokya samyag
Horām Varāhamihiro ruciram cakāra ||
(Br.J. 26.1 (Edn. *Triv. Skt. Ser., No.91)*

Thus VM was the son of Ādityadāsa; he learnt the *śāstra* from his own father; his native place was Kāpitthaka; he was blessed by Lord Sun (at Kāpitthaka). He (later) resided at Avanti (Ujjain) where he composed his work *Horā (Bṛhajjātaka)*. On Kapitthaka VM's commentator Utpala says : *Kāpitthākhye grāme yo 'sau bhagavān savitā sūryaḥ, tasmāt labdhaḥ prāpto varaḥ prasādo yena* ('In the village of Kāpittha where he received the blessing of God Sun'). Kāpitthaka, the native village of VM, has been identified by Ajay Mitra Shastri (vide his *India as seen by Varāhamihira*, (MLBD, Delhi, 1969, p.19) on the basis of the mention thereof by 7th century Chinese traveller Yuan Chwang with Kāpittha populary known as "Saṅkāśya (modern Sankisa) in the Farrukhabad district of Uttar Pradesh...."

Utpala states in his commentary on VM's *Bṛhatsaṁhitā* (I.1) that VM was a 'Magadhadvija' : *tad ayam apy Āvantyakācāryo Magadhadvija-Varāhamihiraḥ arkalabdhavaraprasādo jyotiśśāstrasaṅgrahakṛt*, (Ed. Sarasvati Bhavana Granthamālā, Varanasi, 1968, p.2). Utpala makes such a statement also in his commentary on VM's *Yogayātrā*. This and the surname *'Mihira'* which is borne by many Śākadvīpa brāhmaṇas, who are worshippers of the Sun, would indicate that VM belonged to this clan of Brāhmaṇas whose forefathers migrated to India from the Maga country in Persia and settled in the village of Kāpitthaka whence VM came to the city of Ujjain where he wrote his works.

By all accounts, Varāhamihira had the Sun as his tutelary deity. To quote A.M. Shastri (op. cit., pp. 20-21) :

> 'That Varāhamihira was a devotee of the Sun admits of no doubt. His father's name was Ādityadāsa, his own name-ending 'Mihira', derived from 'Mithra', the Iranian Sun-god, his obtaining a boon from the Sun, his obeisance to the Sun in all his works except the *Vivāhapaṭala*, (which, appropriately enough, opens with an invocation to Kāma, the Indian god of love), and his devoting a comparatively larger number of verses to the description of Sūrya icons, all indicate that the sun was his family deity. His son Pṛthuyaśas also invokes the Sun in the opening verse of his *Ṣaṭpañcāśikā*. As we have seen, Varāhamihira was regarded as an incarnation of the Sun.'

The fame of VM has given rise to several legends about his birth and incidents in his life, including his being a courtier of King Vikrama and one of the nine gems (*nava-ratnas*) in his court. All these have to be considered as more fable and eological, not based on facts.

Varāhamihira was an astute astronomer and astrologer and wrote extensively on all the three branches of the science, *viz.*, *Tantra* or mathematical astronomy, *Horā (Jātaka)* or horoscopy, and *Saṁhitā* or mundane or natural astrology. It is interesting that for all his major works, VM has prepared abridged versions also for the benefit of those who desist from works which are too lengthy, who, as Utpala says, are *vistaragrantha-bhīru-s*.

On Tantra the major work of VM is the *Pañcasiddhāntikā* in eighteen chapters. It would seem from a statement of Utpala towards the beginning of his commentary on VM's *Laghujātaka* that VM had prepared on abridgement also of that work *Cf. Varāhamihira ..... jyotiśśāstrasaṅgraham kṛtvā tadeva vistara-grantha-bhīrūṇaṁ kṛte' 'saṅkṣiptam gaṇitaśāstram' kṛtvā horāśāstram vaktukāmaḥ* etc.

On horoscopy VM has produced two works, the *Bṛhajjātaka,* called also *Horāśāstra* in 26 chapters, and its abridged version, the *Laghujātaka*, called also *Svalpa-jātaka* and *Sūkṣmajātaka*, in thirteen chapters.

On natural or mundane astrology also VM has two works, the *Bṛhatsaṁhitā* called also *Vārāhī-saṁhitā* in 106 chapters and *Samāsasaṁhitā*, known also as *Laghu-saṁhitā* and *Svalpa-saṁhitā* known through quotations. These are works of an encyclopaedic nature, dealing with astrological and many other subjects of human interest, such as architecture and iconography, water divining, omens, cosmetics, horticulture, characteristics of animals, gemmology, weapons, species of men and women and their qualities and the like. A wide range of information on the geography of India and its people is also to be round in the *Bṛhatsaṁhitā. Vaṭakaṇikā*, which exists only in the form of quotations, is a work of VM on omens.

On military astrology, three works of VM are available; (i) *Mahāyātrā,* known also as *Bṛhadyātrā, Bṛhadyogayātrā, Yakṣyeśvamedhikāh-yatrā* (based in the commencing expression *yakṣye 'svamedhena vijitya* in the second verse of the work), (ii) *Svalpayātrā* or *Ṭikaṇikāyātrā*, and (iii) *Yogayātrā*.

On marital horoscopy, VM has written a work entitled *Vivāhapatala,* and according to Utpala, there is also a *Svalpavivāhapaṭala* (vide. his com. on *Bṛhajjātaka* XX.10). More than 30 more texts are mentioned, in manuscripts and elsewhere, to have been composed by VM (Cf. A.M. Shastri, *op. cit.*, pp. 29-31) but these lack authenticity in their ascription.

Alongside his wide range of scholarship, VM's writings are also characterised by chaste language, brevity and linguistic elegance. He is a master not only of expression but also of metre. In illustration of his poetic talents one might refer to the figures of speech expressed through verses XIX. 13-15 of the *Bṛhatsaṁhitā* describing Agastyodaya, the rising of the star Agastya. In the same work, *Bṛhatsamhitā,* he utilises the entire chapter 104, containing 64 verses, the *Gocarādhyāya* ('Transits of planets'), to illustrate the metres, including the *daṇḍaka*-s, alongside depicting the subject proper. It is also instructive that the names of the several metres are also deftly incorporated in the verses by means of *śleṣa* or *double entandre.* Utpala is not, perhaps off the mark when he says, towards the commencement of his commentary on *Bṛhatsaṁhitā*, extolling VM as an incarnation of the Sun :

> *Yac cāstram savitā cakāra vipulam skandhatrayair jyautiṣam*
> *tasyocchittibhayāt punaḥ kaliyuge saṁsṛjya yo bhūtalam |*
> *bhūyaḥ svalpataram Varāhamihira-vyājena sarvam vyadhād*
> *ittham yam pravadanti mokṣakuśalās tasmai namo bhāsvate*

'The science of Jyautiṣa in its triple aspects (of *Tantra, Jātaka,* and *Saṁhitā)* was propounded at length by God Sun. Fearing that it would be lost in the Kali age, God Sun incarnated in the world in the form of Varāhamihira and expounded all (the said three aspects) again in shorter form. So say about the Sun those who are knowledgeable about salvation. Obeisance to that Sun.'

Madras
January 4, 1993

K.V. SARMA

पञ्चसिद्धान्तिका

PAŃCASIDDHĀNTIKĀ

Chapter One

INTRODUCTION OF THE WORK

१. प्रथमोऽध्यायः

करणावतारः

[ग्रन्थोद्देशः]

दिनकरवसिष्ठपूर्वान् विविधमुनीन्द्रान् प्रणम्य भक्त्यादौ |
जनकं गुरुं च शास्त्रे येनास्मिन् नः कृतो बोधः || १ ||
पूर्वाचार्यमतेभ्यो [यद्] यच्छ्रेष्ठं लघु स्फुटं बीजम् |
तत्तदिहावि[क]लमहं रहस्यमभ्युद्यतो वक्तुम् || २ ||

Aim of the Work

1-2. After saluting, at the outset, with great devotion, the various great sages like Sūrya, Vasiṣṭha, and others, and my father and teacher who taught me this *śāstra*, I shall state in full the best of the secret lore of astronomy extracted from the different schools of the ancient teachers so as to be easy and clear.

Mss used

A_1. BORI, Poona, Ms No. 338/1879-80; A_2. National Library, Calcutta, Ms No. 49. B_1. BORI, Ms No. 37/1874-75; B_2. Or. Inst., Baroda, Ms No. 7165; B_3. National Library, Ms No. 64. C. Readings/Emendations in the edn. of PS by Thibaut-Sudhakara Dvivedi, Varanasi, 1889; Rep. 1938, 1968. D. Readings/Emendations in the edition of PS by Naugebauer - Pingree, Munksgaard, 1970.

External Testimonia (E)

Jy. *PS* Quotations in the *Jyotirmīmāṃsā* of Nilakaṇṭha Somayāji
M. Quotations in Makkibhaṭṭa's Com. on the *Siddhāntaśekhara* of Śrīpati
N. Quotations in Nīlakaṇṭha Somayāji's Com. on the *Āryabhaṭīya*
Pa. Quotations in Parameśvara's Com. on the *Āryabhaṭīya*
Pr. Quotations in Pṛthūdaka's Com. on the *Brāhmasphuṭasiddhānta*
S. Quotations in Sūryadevayajvan's Com. on the *Āryabhaṭīya*
U. Quotations in Utpala's Com. on the *Bṛhatsaṃhitā*. *(BS)*.

A1.2. Begin with: श्री रामचाय नमः
B1. Begins: पञ्चसिद्धान्तिका । ; B2. Begins: श्रीगणेशाय नमः । अथ श्रीपञ्चसिद्धान्तिका लिख्यते । B3. Beginning lost.
C. Begins: [श्रीः । अथ पञ्चसिद्धान्तिका वराहमिहिरकृताऽऽरभ्यते ।] श्री रामच[न्द्र]ाय नमः ।
D. Begins: [श्रीवराहमिहिरविरचिता पञ्चसिद्धान्तिका प्रारभ्यते ।] श्री रामच[न्द्र]ाय नमः ।
1. Quoted by Utpala on BS 2.2
1a. B1. वशिष्ट; B2. वशिष्ठ
b. B1. मुनिन्द्रा; U. मुनीन् भावतः प्रणम्यादौ
2b. A1.2.B.1.3 ०भ्यो यच्छ्रेष्ट लघु
c. A1..2. तत्कृदिहाविलमहं; B1.2. तत्तदिहाखिलमहं

In the second verse, the letter *ka* has been added to supply the one syllable wanting and in keeping with the sense. The Sun being the *Ātman* of the Universe and also the chief of the *grahas*, all the gods and all the *grahas* are propitiated by His worship. By the expression 'various great sages' the author means the eighteen primary authors of the *Siddhāntas* on astronomy, viz. Sūrya, Soma, Pitāmaha, Vasiṣṭha, Atri, Parāśara, Kāśyapa, Nārada, Gārgya, Marīci, Manu, Aṅgiras, Romaśa, Paurukutsa, Cyavana, Yavana, Bhṛgu and Śaunaka and, by saluting these, the author salutes all ancient authors who follow these *Siddhāntas*.

[पञ्च सिद्धान्ताः]

पौलिश-रोमक-वासिष्ठ-सौर-पैतामहास्तु पञ्च सिद्धान्ताः ।
पञ्चभ्यो द्वावाद्यौ व्याख्यातौ लाटदेवेन || ३ ||

The Five Schools of Astronomy

3. The five *Siddhāntas*, of which this work is a compendium, are the *Pauliśa*, the *Romaka*, the *Vāsiṣṭha*, the *Saura* and the *Paitāmaha*. Of these five, the first two, viz., the *Pauliśa* and the *Romaka* have been commented upon by Lāṭadeva.

Of the *Siddhāntas* here mentioned, Brahmā is the author of the *Paitāmaha;* Vāsiṣṭha, that of *Vāsiṣṭha;* Pauliśa that of *Pauliśa;* Romaka that of *Romaka;* and Sūrya, that of *Saura*. From a dialogue between Sūrya and Aruṇa, it can be learnt how these five *Siddhāntas* were given to their respective recipients. According to tradition, at the first instance, Brahmā saw this lore of astronomy embedded in the Vedas and extracted it in the form of the *Paitāmaha*. He taught this to his son, Vasiṣṭha at the behest of Viṣṇu and again to Sūrya who was created with the express purpose of giving Time to the Universe. Vasiṣṭha gave this lore to his son, Parāśara who, in turn gave the *Parāśara Siddhānta* to the sages. One sage, Pauliśa taught this to the sages Garga etc. and this is the *Pauliśa Siddhānta*. Sūrya himself, being born among the Yavanas by the curse of Brahmā, taught the science to Romaka and Duryavana in the city of Romaka, and Romaka propounded it as the *Romaka Siddhānta*. Thus these five *Siddhāntas* are the most ancient.

It is to be noted here that the five *Siddhāntas* used by the author in his work are all different from works of the same name current at present and it seems they have been lost to us. The *Pauliśa* used by the author is different from the *Pauliśa* quoted by Bhaṭṭotpala in his commentary on the *Bṛhatsaṁhitā* which latter agrees with the *Saura* of our author and disagrees with his *Pauliśa*. The *Romaka* and *Vāsiṣṭha* now extant are different from those of VM, agreeing as they do with the now well-known *Sūrya Siddhānta*, (called by scholars as the *'Modern'* or *'Later' Sūrya Siddhānta* to distinguish it from the ancient *Saura Siddhānta*). The author's *Saura* does not agree with the *'Modern' Sūrya Siddhānta*, though one would expect agreement from the similarity in name, but it agrees with a work of the ancient Āryabhaṭa, now lost to us, and called by his commentator Bhāskara I as the *Ārdharātra-Pakṣa*, which again is the basis of the *Khaṇḍa-khādyaka-karaṇa* of Brahmagupta. As for

3. Quoted in the Jyotirmīmāṃsā (Jy) of Nīlakaṇṭha, p.7.

a. A1. पैलिश
B1. रोमयु; Jy. रोमश
B1.2. वाशिष्ट; A1.2. वासिष्ट

b. A1. पैतामहास्तु

c. B1.2. पञ्चेभ्यो
A1. द्वावाद्यो; A2. द्वावोद्यौ; Jy. द्वावन्त्यौ

the *Paitāmaha*, there are several works now extant claiming Pitāmaha or Brahmā for their author. One is the *Brahma Siddhānta* given by Brahmā to Nārada, which follows the '*Modern*' *Sūrya Siddhānta* in its constants. Another is the *Pitāmaha Siddhānta*, forming a part of *Viṣṇudharmottara*, which has been taken by Brahmagupta as the basis of his *Brāhma-Sphuṭa Siddhānta*. A third one, now lost, is the basis of the *Āryabhaṭīya*. But the *Paitāmaha* of our author is different from all these.

As for the Lāṭadeva mentioned here, he is the Lāṭācārya referred to in XV.18 of this work, for, there, the author says that this Ācārya has taken sunset at Yavanapura as the beginning of the day and from I.8. we understand that the *Pauliśa* and *Romaka* do the same and here it is mentioned that Lāṭadeva is the commentator of these two *Siddhāntas*.

पौलिशतिथिः स्फुटोऽसौ तस्यासन्नस्तु रोमकप्रोक्तः |
स्पष्टतरः सावित्रः परिशेषौ दूरविभ्रष्टौ || ४ ||

4. The *tithi* resulting from the *Pauliśa* is tolerably accurate and that of the *Romaka* approximate to that. The *tithi* of the *Saura* is very accurate. But that of the remaining two (viz. the *Vāsiṣṭha* and the *Paitāmaha*) have slipped far away (from the real).

The five *Siddhāntas* are compared here with reference to their *tithi* alone because that is the chief of the five *aṅgas*, viz. *tithi*, *vāra*, *nakṣatra*, *yoga* and *karaṇa*, that is most useful not only for religious but also civil purposes, that is independent of the origin of reference in the ecliptic and can be examined for correctness by observation of eclipses and heliacal rising and that is used in finding the days from Epoch, the *sine qua non* of all astronomical computation. This being the case, the change of '*tithi*' into '*kṛta*' by the late Dr. G. Thitbaut and M.M. Sudhakara Dvivedi (TS for short), especially when the manuscripts read only *tithi* or *tithaḥ*, is unwaranted, to say the least. Doing this, they have condemned the *Vāsiṣṭha Siddhānta* beyond the author's intention and become blind to its merits and peculiarities, which otherwise they could easily have seen. Equally off the mark is the emendation of *tithi* into *stvatha* by Neugebauer and Pingree (NP, for short). See below, explanatory Notes, for the real reason for this 'slipping far away from the real'.

[प्रतिपाद्यवस्तु]

यत्तत्परं रहस्यं भ्रमति मतिर्यत्र तंत्रकाराणाम् |
तदहमपहाय मत्सरमस्मिन् वक्ष्ये ग्रहं भानोः || ५ ||

दिक्स्थितिविमर्दकर्णप्रमाणवेला ग्रहाग्रहाविन्दोः |
ताराग्रहसंयोगं देशान्तरसाधनं चास्मिन् || ६ ||

4. Quoted in the Jyotirmīmāṃsā (Jy) P.7.
a. A1.2. पौलिशतिथि स्फु°; B1.2. पौलिशतिथः ;
C. पौलिश [कृत];
D. पौलिश [स्त्वथ]; Jy. पौलिश इति
A.2. स्फुटोद्यौ
b. A1. °सन्नस्तु
A1.2. रोमकः; Jy. रोमशः
c. B1.2. °तरसावित्रः; D. °तरः सवित्रः
d. A1. दुरं
A1.2. °विभ्रष्टौ

समममण्डलचन्द्रोदययंत्रच्छेद्यानि (शाङ्कवच्छायाः) |
उपकरणाद्यक्षज्यावलम्बकापक्रमाद्यानि || ७ ||

Contents of the Work

5-7. I shall tell in this work, avoiding all jealousy, the computation of the solar eclipse, which is guarded as a great secret and in which the mind of the astronomer reels. I shall also tell the occurrence or non-occurrence of the lunar eclipse, the directions of the first and last contacts, the duration, the total phase, the 'hypotenuse' at any moment with related quantity of obscuration and time and also the mutual conjunctions of the stars and the planets and the computation of differences in longitude as also the prime vertical, moonrise, astronomical instruments and other requirements, graphical representations, the gnomonic shadow, the sines of latitude, co-latitude and declinations and such other matters.

The textual recording *tāḍavacchāyā* is emended as *śāṅkavacchāyāḥ* because (i) *tāḍava* is meaningless, and it may be a corruption of *śāṅkava* meaning relating to the *śaṅku* or gnomon which is suggested by the juxtaposition with *chāyā* meaning 'shadow' and (ii) *chāyā* must be *chāyāḥ* because grammer requires the accusative case of the word. TS, NP take the word as *śāṅkavacchāyā*, without the final *visarga*.

As for the mention of the computation of the solar eclipse as a 'great secret' it is because of the difficulty of the computation which, therefore, would bring honour to a person who can do it and for that reason not given to all. From the contents we can see the importance of the work for religious purposes.

The technical words that occur here like prime vertical etc. will be explained in their respective contexts.

[रोमकसिद्धान्तानुसारी अहर्गणः]

'सप्ताश्विवेद'संख्यं शककालमपास्य चैत्रशुक्लादौ |
अर्धास्तमिते भानौ यवनपुरे सोमदिवसाद्यः || ८ ||
मासीकृते समासे (द्विष्ठे) सप्ताहतेऽ'ष्टयम(पक्षैः') |
लब्धैर्युतोऽधिमासैस्त्रिंशद्घ्नस्तिथियुतो द्विष्ठः || ९ ||

5a. B1.यत्तत्पैरं; B2.यतत्पैरं
c. B1.मक्षर°
d. A1.वक्षे; B1.2.वद्दये
6a. B1.दिक् सस्थिति; B2.दिक्क मस्थि
c. A2.ताराग्नं योगं
d. A1.2.सावनं

7b. B1.यत्र°; B2.कर्धप्र°
A2.छेप्रानि
A1.तावछाया; A2. B2.ताडवछाया;
B1.ताष्टवछाया; C.D.शाङ्कवच्छाया
e. B1.2.उपकारणा°
D.°णान्यक्षन्या
d. B1.2.°वलम्बपक्रमा°

'रुद्र'-घ्नः स'मनुशरो' लब्धोन'गुणखसप्त'भिर्द्युगणः |
रोमकसिद्धान्तेऽयं नातिचिरे पौलिशेऽप्येवम् ||१० ||

Days from Epoch according to Romaka

8-10. Deduct 427 from the Śaka year (elapsed) of the time taken. Multiply the remainder by 12. Add the months gone, counting from Caitra. Put this result in two places. In one place, multiply it by 7, divide by 228 and take the quotient which constitute the intercalary months. Add this to the result kept in the second place. (The total are the synodic months gone.) Multiply this by 30 and add the *tithis* counted from *śukla-pratipad* to the current *tithi.* Put the sum in two places. In one place multiply by 11, add 514, divide by 703 and take the quotient, (which constitute the elided days or *avamas*). Deduct this from the sum put in the other place. The remainder are the 'Days from Epoch' (*dyugaṇa*), the moment of Epoch being mid-sunset at Yavanapura, beginning Monday when the first *tithi* of Caitra was about to begin.

This rule is according to the *Romaka.* It can be taken as the *Pauliśa* rule also, provided the time taken for computation is not very far from the Epoch. (*or* the part of the rule for *avama* may be used for the *Pauliśa* also, provided the taken date is not very far from the Epoch; *or* in the *Pauliśa* too the movement of Epoch is mid-sunset at Yavanapura, beginning Monday.)

Example 1 . Find the Days from Epoch for Tuesday the sixth day of the dark fortnight of Āṣāḍha, Śaka 499 (elapsed).

Śaka year (elapsed) of date is 499. 499 − 427 = 72 years gone. Months gone = 72 × 12 + months counted from Caitra upto Āṣāḍha = 72 × 12 + 3 = 867.

$867 \times 7 \div 228 = 6069 \div 228 = 26$

$(= Q) + \frac{141}{228} (= \text{Rem})$

	867
Adding the quotient	26
Synodic months gone	893

The *tithis* = 893 × 30 + *tithis* in the current month = 893 × 30 + 21 = 26,811

(26,811 × 11 + 514) ÷ 703 = 420 (= Q) + 175/703 (= Rem)

	26,811
Deducting the quotient	420
Days from Epoch gone	26,391

8-10. Quoted by Utpala on BS 2. (p.30)

8c. A2.अद्धस्त

d. A1.2.सौम्य; B1.2.भौम्य; D.भौम
A1.2.C.D. U.दिवसाद्ये

9a. A2.माग्नीकृते A2.समाग्ने

b. A1.2.द्विष्टे; B1.2.द्विस्थे A1.2.पक्षै; B1.3.पक्ष्यैः

c. B1.युतो त्रिमासैः; B2.युतो छिमासैः

d. A1.2.द्विष्टः; B1.2.द्विस्थः; U.धःस्थः
A1.०शघ्न०

10b. B1.2.लब्ध्योनो B1.यो नाति

c. A1.2.सिद्धांतोयं A2.संदाभि

Dividing 26,391 out by 7, the remainder got is 1, i.e. Monday has gone and Tuesday has begun. (This agrees with the data given and therefore 26,391 are the required days from Epoch.)

The rule is thus explained: According to the *Romaka*, in a *yuga* containing 2850 solar years, there are 1050 intercalary months and 16,547 elided days (vide I.15). From this we can compute that in the *yuga* there are 34,200 solar months, 35,250 synodic months (i.e. months), 10,57,500 *tithis* and 10,40,953 civil days (vide I.17). Now, because the Epoch is 427 Śaka (elapsed), by deducting 427 from the Śaka year (elapsed) of the time taken, the years gone at the taken time from the Epoch is got. As there are 12 solar months in a year, the years gone × 12 + the months gone upto the time taken = the solar months gone from Epoch to the end of the solar month falling in the current month. The intercalary months during this period is obtained by proportion from the solar months and the intercalary months of the *yuga*, viz. 34,200: 1050 :: the solar months gone: the intercalary months during the period. Thus we have the equation, the intercalary months = the solar months gone × 1050 ÷ 34,200. The fraction 1050/34,200 reduces to 7/228 which represents the author's instruction to multiply by 7 and divide by 228 to get the intercalary months. It should be noted that we are finding the intercalary months not upto the taken time but upto the end of the solar months falling in the current month, for, logically, the third member of the proportion should be solar months as the first member is the solar months of the *yuga*. The number of months gone from Caitra upto the time taken is the same as the solar months ending in or before the current month, and therefore, we use it for adding to years gone × 12, to get the solar months gone. From this we can understand that in counting the months from Caitra we should not reckon any intercalary month that has fallen. Note also that the fraction of intercalary month obtained from the proportion is the part of the current synodic month from *pratipad* upto the end of the solar month and by omitting it, we have found the intercalary months gone before the taken time which is the thing wanted.

The rule for 'Days from Epoch' does not mention any constant (*kṣepa*) to be added to the intercalary month obtained because at the time of Epoch there is practically no fraction of intercalary month. We shall now show how it is practically zero. Even though we do not know the time when the Romaka Yuga began, wherefrom the fraction required can be obtained, still from the constant for the mean Sun and Moon in Chapter VIII we can obtain this, in the following manner. There, in the first verse giving the rule for the mean Sun, 150 is mentioned as the multiplier for the Days from Epoch, and 65 is given as the subtractive constant. From this we learn that 65/150 days, (i.e. 26 *nāḍikās*) after Epoch, the mean solar month ends and therefore at Epoch the mean Sun is $11^r 29° 34' 30''$. Again, from the constants in the fourth verse giving the mean Moon, we can learn that the mean Moon at Epoch is $11^r 26° 12'$. From these, it can be computed that the mean new moon occurs about 16½ *nāḍikās* after Epoch. As the interval from new moon to the end of the solar month is the fraction of intercalary month, we get 26 − 16½ = 9½ *nāḍikās*, as the fraction. As for one intercalary month consisting of about 29½ days there are 228 parts as constant, for 9½ *nāḍikās* we get 1 as constant. This is omitted as being negligible, because, after all, we are going to use in the rule not the mean Caitra, etc. but the true Caitra etc. which can differ from the mean upto 36 *nāḍikās*. That is why if an intercalary month has actually fallen in the current year before the taken time, we take the fraction of the computed intercalary month as whole and add one, and if no intercalary month has fallen we omit one from the computed months when the fraction left over is small.

To continue, adding the intercalary months to the solar, the synodic months gone are got, for the intercalary months are the synodic months omitted in the one to one correspondence of the synodic months with the solar. Multiplying the total synodic months by 30 and adding the *tithis* in

the current month, the total *tithis* are obtained. These lessened by the number of elided days in the period between the Epoch and the time taken gives the Days from Epoch, for the elided days are the *tithis* left out of reckoning in one to one correspondence between the *tithis* and the days. Here the elided days are obtained by the proportion, if for the *tithis* in the *yuga* numbering 10,57,500 there are 16,547 elided days, how many elided days are there for the *tithis* from the Epoch to the taken time; i.e. 10,57,500 : 16,547 :: the intervening *tithis*: the intervening elided days. So, we have the equation, the intervening *tithis* × 16,547 ÷ 10,57,500 = the elided days. Here the multiplier for the *tithis*, viz., the fraction 16,547/10,57,500 can be expressed as a continued fraction to find a suitable smaller fraction for easy work, thus:

1	16547	1057500	63
1	1508	15039	9
1	41	1467	35
1	9	32	3
4	4	5	1
	0	1	

i.e. $16{,}547/10{,}57{,}500 = \frac{1}{63+}\,\frac{1}{1+}\,\frac{1}{9+}\,\frac{1}{1+}\,\frac{1}{35+}\,\frac{1}{1+}\,\frac{1}{3+}\,\frac{1}{1+}\,\frac{1}{4+}$

The successive convergents obtained from this are: 1/63, 1/64, 10/639, 11/703, 395/25244 etc. Of these the author has taken 11/703 as being simple and, at the same time, sufficiently accurate for the purposes of this work, for even during a period as large as the *yuga*, the difference in the elided days will be only 10,57,500 (1654/10,57,500 − 11/703) = 1/17, and this is small in comparison with the difference caused by actually using the true *tithi* in the formula, which we are constrained to use, in the place of the mean *tithi* which, according to theory we must use.

Now, at the time of Epoch there was a fraction of elided day equal to 514/703, and, as this has also to be added, the additive constant 514 is given. As done in the case of the intercalary month, here also we can examine the correctness of the constant, 514, thus: the fraction of elided day is the part of the current *tithi* gone before the time of beginning of the new day, as in the present case, viz., the *Romaka* before sunset at Yavanapura. We have seen before that at Epoch there remains 16½ *nāḍikās* for the mean new moon to end, i.e. about 43 *nāḍikās* have ended in mean Amāvāsyā tithi. The constant 514 means that 514/703 part of the Amāvāsyā has gone and this is equal to about 43 *nāḍikās* and thus the constant is practically correct. It is because of the existence of this constant that we have interpreted, *caitra-śuklādau* as 'when the first *tithi* of Caitra was *about* to begin'. Further, we have seen that at Epoch Amāvāsyā is current and Caturdaśī is gone. But, taking the Amāvāsyā as gone, the *tithis* to be used in the formula are asked to be reckoned from the first *tithi* of the month. That is why we gave the instruction to add the *tithis* from Śukla-Pratipad to the *current tithi*, though the usual instruction would be to add only the *tithis* gone. It must be noted that the author's instruction is simpler and at the same time not incorrect. Also, there is the usual practice of comparing the week day for the obtained Days from Epoch, with the actual week day of the taken time, and adding or subtracting a day from the days got, if necessary, which will take care of everything. Thus the whole thing is explained.

The *Śaka year* is the year of the Śaka era which began at 3179 Kali (elapsed), for the *Siddhāntas* instruct that 3179 should be added to the Śaka year to get the Kali year. The purpose of mentioning that *Caitra Śukla Pratipad* occurred near the Epoch is to indicate that the months gone must be

counted from Caitra and the *tithis* from Śukla Pratipad. The moment of Epoch is given as mid-sunset at Yavanapura, because the Sun has an angular diameter of about 32′, and the time between the beginning and end of its immersion below the horizon is considerable. The practice of beginning the day at sunset was, in those days, prevalent in the countries near Yavanapura, which practice is still followed by Jews and Muslims, as in India certain *Siddhāntas* like the *Sūrya Siddhānta* begin the day at midnight, which is used for certain injunctions of the *Dharma-śāstras*, while certain other works like the *Āryabhaṭīya* etc. begin the day at sunrise which is used for certain other injunctions of the *Dharma-śāstras*.

Yavanapura is Alexandria in Egypt, the ancient capital of the country, where Ptolemy II, the famous astronomer and author of the *Almagest*, ruled and which was well known to the astronomers of India. How do we know that it is Alexandria and no other city? In III. 13 the time-difference between Yavanapura and Ujjain due to their difference in longitude is given as seven *nāḍis* and twenty *vināḍis* and sunset at Yavanapura is later. From this we can see that it must be a well known place 44° west of Ujjain in longitude and its position agrees with that of Alexandria.

We have said that the moment of Epoch begins Monday, *somadivasādye*. This reading is that of Bhaṭṭotpala, quoting the verse in his commentary of the *Bṛhatsaṃhitā* and we have adopted it as the correct one. It does not matter if we adopt another reading, *saumyadivasādye*, for we can interpret this as 'the day pertaining to the Moon', i.e. Monday, because the word *saumya* can be interpreted as 'belonging or pertaining to the Moon'. It cannot mean Wednesday, as it might appear at first sight, (the word *saumya* being a name for Mercury), for it must be Monday because the Lord of that day as computed from I.20 is the Moon and not Mercury. We shall show how. In I.17 it is instructed that 2227 should be added to the Days from Epoch to get the lords of the year, month, day and *horā*. Because the Days from Epoch gone is patently zero at the Epoch itself, we have 2227 + 0 = 2227, from which to get the Lord of the day. The instruction is to divide this out by seven, and take the remainder, which gives the Lord of the day gone counting from the Sun, in the order Sun, Moon, Mars etc. Now we want the Lord of the 2228th day, and dividing 2228 by 7, the remainder is 2, i.e. Moon is the Lord of the day and it must be Monday. This can be shown in other ways also but this is enough here. When there is this fact of a Monday and the reading *somadivasādye* to support it, the interpretation by some as 'at the beginning of Wednesday' has to be discarded. There is another reading, *bhaumadivasa* which has been accepted by the two scholars, S.B. Dikshit and Bhau Daji, and also by NP, not remembering that the formula has been and can be constructed only on the basis of the mean constants and not of the true constants and not understanding the purpose of the statement *caitraśuklādau*, as such that reading has also to be discarded. Note also that the Romaka *ahargaṇa* mentioned in verse 17 below, viz. 2227, works out only to Monday, not Tuesday, since the cycle commences from Sunday.

We have given as one interpretation of *nāticire Pauliśe 'py evam*, 'It can be taken as the *Pauliśa* rule also, provided the time taken for computation is not very far from the Epoch'. Strictly speaking, in the rule given by a particular *Siddhānta*, only the synodic month and the *tithi* of that *Siddhānta* must be used to get the Days from Epoch. But as given in I.4, the *tithi* of the *Romaka* was near that of *Pauliśa* at the time of Epoch and so the *Romaka* rule could be used for the *Pauliśa* for some time, especially because there is the check by comparing the week-days. Another thing to be noted is this: Whatever *Siddhānta* is used to compute the days from Epoch, the result must be the same. That is why no separate rule has been given either for the *Vāsiṣṭha* or for the *Saura*, for we can use days of the *Romaka* or *Pauliśa* for these also, *mutatis mutandis*.

TS interpret *nāticire Pauliśe' py evam* as 'the rule is the same for also the *Pauliśa Siddhānta* which was

written not long ago'. But the time of a work is irrelevant to a manual of the sort the author is writing and he is not interested in giving it. As a result of this interpretation, they have taken that the *Pauliśa* rule is the *same* as the *Romaka* rule, with the result that they have not been able to see that the following verses 11-13 give the rule of the *Pauliśa*, though they are quite capable of understanding and interpreting them. NP translate, 'It is not very different in the Pauliśa', without explaining *nāticire*.

[पौलिशसिद्धान्तानुसारी अहर्गणः]

'दि'ग्घनाः सा'ष्टनवरसा' दिवसा ('एकर्तु)सप्तनव'भक्ताः |
पौलिशमतेऽधिमासाः 'त्रिकृत'दिनान्यवमसंक्षेपः || ११ ||

Days from Epoch according to Pauliśa

11. (The formula for Days from Epoch according to the Pauliśa, is as follows:) As in Romaka (I.8-10), deduct 427 from the Śaka year (elapsed). Multiply by 12 and add the months gone from Caitra. Multiply by 30. The 'Solar days' (S-days) to the end of the current solar month are got.

Multiply the S-days by 10, add 698, and divide by 9761. The quotient are the intercalary months. (Again, as in Romaka), multiply the months got by 30 and add to the S-days, and add also the *tithis* from śukla-pratipad, *inclusive* of the current *tithi*. The sum is the *tithis* gone from Epoch. Multiply this by 11, add 444 (*tri-kṛta*) and divide by 703. The quotient are the elided days. Deduct this from the *tithis* gone. The remainder are the Days from Epoch.

Here the word *divasāḥ* is interpreted as *ravi-divasāḥ*, i.e. 'solar days', because it comes in the place of 'solar months' in the formula. The number of 'solar days' is equal the number of degrees traversed by the Sun, the time taken for moving one degree being taken as one 'solar day' by Indian astronomers. It is not what is meant in modern astronomy, the time interval taken by the Sun for the successive crossing of the meridian.

To avoid error of syntax, '*sāṣṭānavarasa*' is emended into '*sāṣṭanavarasā*'. Following the sense, in the place of *kurtu* and *rutu*, the reading *ekartu* is substituted. NP editorially add before *divasāḥ* the word *saura*, which is not necessary, as it can be inferred. NP's translation gives the number 9761 with an emended reading *kvṛtusaptanava*. Again, the ms. reading *tri-kṛta* has been changed to *tri-ṣaṭ*, with the translation, 'there is an omitted tithi every 63 days', missing to see that *tri-kṛta* (444) is the Pauliśa *kṣepa* in place of the Romaka *kṣepa* 514 of the previous verse, to be used in the Pauliśa calculation.

11a. A1.2.D. दिघ्नाः; C. दिघ्ना
A1.2.B1.2. साष्टा
A1.2.C. नवरस; D. नवरसाः [सौर] दि०
b. A1.2. B1.2. om. ए
A1.2. कृर्तु; B1.2. रुतु; C. क्रतु; D. [कृतु]
c. C. त्रिऋतु; D. त्रि [षड्]
d. B2. ०नान्यिवम०
A1.2. संशेषा

तिथिदश(मांशं) दद्यादधिमासार्थं 'स्वराम्बरैका'ब्दैः ।
अवमार्थं 'पञ्चकृतद्वि'संमितैस्तिथि'शिवां'शं च ॥ १२ ॥
अधिमासकेषु भूयोऽप्येकीकर्तुं 'खपञ्चकेन्द्रियां'शेषु ।
देयोऽवमेषु हेयो 'नवसप्तद्वित्रिखयमे'षु ॥१३ ॥

12-13. (For greater accuracy in finding the intercalary months by the above formula,) add 1/10 S-day to the S-days for every 107 years and for still greater accuracy, add an extra 1/10 S-day for every 550 such 1/10 S-days added, (i.e., for 55 S-days added). In the same way, in getting the elided days, for every 245 years add 1/11 *tithi* to the *tithis* gone and for every 2,03,279 such additions omit one addition.

What is the purpose of the author in aiming at such accuracy? The author intends that the *Pauliśa* should be used by people for a very long time as can be seen by his giving it fully in this work. (He gives the *Saura* also fully with the same view.) So he wishes to secure greater accuracy for the Days from Epoch got by the *Pauliśa*.

Example 2 . The day taken is Monday, Mārgaśīrṣa Amāvāsyā, Śaka 1821 (elapsed). Find the days from Epoch, for the moment of the beginning of the day.

The S-days to the end of the Solar month in the current synodic month = {(1821 − 427) 12 + 8} × 30 = 5,02,080. The tenths of solar days to be added to this for computing the intercalary months accurately = (1821 − 427) ÷ 107 = 13. Adding 5,02,080 +1 3/10 = 5,02,081 3/10. Multiplying by 10, adding 698 and dividing by 9761, the intercalary months got are: (5,02,0813 + 698) ÷ 9761 = 514 4357/9761. Taking the full months, multiplying by 30, adding the *tithis* inclusive of Amāvāsyā and adding to the S-days, the *tithis* gone are 514 × 30 + 30 + 5,02,080 = 5,17,530. The elevenths of *tithis* to be added to this for accurately computing the elided days = (1821 − 427) ÷ 245 = 5. Adding to the *tithis* gone, multiplying by 11, adding 444 and dividing by 703, the elided days obtained are {(5,17,530 + 5/11) × 11 + 444 } ÷ 703 = 8098 385/703. Deducting the full elided days from the *tithis* gone, the Days from Epoch gone = 5,17,530 − 8098 = 5,09,432. Dividing out by 7, the remainder is 0, i.e. Monday is beginning. This agrees with the weekday of the taken time, viz. Monday, and therefore the Days from Epoch are 5,09,432.

Now, for the explanation of the *Pauliśa* rule. Before proceeding, the following things should be noted: (1) The text here is badly vitiated, (2) the original *Pauliśa* has been lost, and no *Siddhānta* with

12a. A1.दशमथ द॰; A2.दश-gap-मद॰
B1.2.दशदद्यादमांश; C.दशशद॰; D.दशांश[मथ] द॰
b. B1.2.दौधमासार्थं
A1.2.स्वरांत्वरैः काब्दैः; B1.2.खराम्बरैः काब्दैः
c. B1.2.अवमाथ
A1. B1.C.पंचकृता; A2.पंचसता
c-d. A1.द्विकुमितै; A2.द्विक्रुमितै; B1.2.द्विसंस्थितै;
C.द्वित्रिमितै; D.पञ्चतनुद्विद्विमितैः
d. A1.2.शिवांशैश्र्वः; B1.2. C.D.शिवांशैश्र्च;
13a. B1.अधिमासयेषु; B2.अधिमासयेष्टु
b. D. [त्येक ऋतुखपञ्च];
B1.2.॰केन्द्रियादेव D.केन्द्रियाब्देषु
c. B1.2.॰वमेष्ट
B1.न्यवसप्र

the constants of the original *Pauliśa* is extant so that the constants here given cannot be verified directly; (3) the condensed *Pauliśa* of our author does not give the mean Moon. But as the *Vāsiṣṭha* and the *Pauliśa* are found mixed together in this work and as some peculiar technical terms are found common to both, we can assume that they are connected in some way and the *Vāsiṣṭha* Moon is intended for the *Pauliśa* also. Now we can explain the rule.

From III.1 we learn that there are 43,831 days in 120 Solar years. From II.3 we learn that in a period of 3031 days, called a *Ghana*, the mean Moon moves through 110 full revolutions 11 signs, 7 degrees and 32 minutes. Assuming that no fraction of a minute has been added or left out, the motion for the period in revolutions is 110 + 11/12 + 7/12 × 30 + 32/12 × 30 × 60 = 110 5063/5400 = 5,99,063/5400. The days for 5,99,063 revolutions are, 5,99,063 × 3031 ÷ (5,99,063/5400) = 5400 × 3031 = 1,63,67,400. For 1,63,67,400 × 43,831 = 7,17,39,95,09,400 days, the Moon's revolutions are 5,99,063 × 43,831 = 26,25,75,30,353. In the same way, the mean Sun's revolutions in the period of 7,17,39,95,09,400 days are 120 × 1,63,67,400 = 1,96,40,88,000. Therefore, using I.16, in a period of 7,17,39,95,09,400 days,
there are 26,25,75,30,353 revolutions of the Moon,
and there are *1,96,40,88,000* revolutions of the Sun.
Subtracting, there 24,29,34,42,353 synodic months,
Multiplying Sun's rev. by 12 there are *23,56,90,56,000* solar months,
Subtracting, there are 72,43,86,353 intercalary months.
Multiplying synodic months by 30 there are 7,28,80,32,70,590 *tithis*.
Now, the days are, as above 7,17,39,95,09,400.
Subtracting the days, there are 11,40,37,61,190 elided days.

From this we can see that in a period of 23,56,90,56,000 solar months, i.e. for 7,07,07,16,80,000 'solar days' there are 72,43,86,353 intercalary months. So, by proportion we find the intercalary months for the given solar days by 7,07,07,16,80,000 : 72,43,86,353 :: S-days : intercalary months, i.e. intercalary months = S-days × 72,43,86,353/7,07,07,16,80,000. The multiplying fraction here, viz., 72,43,86,353/7,07,07,16,80,000, can be expressed as a continued fraction thus =

10	724386353	707071680000	976
1	18391633	70599472	3
5	2967080	15424553	5
	21315	589153	
	....	....	

$$72{,}43{,}86{,}353/7{,}07{,}07{,}16{,}80{,}000 = \frac{1}{976+}\ \frac{1}{10+}\ \frac{1}{3+}\ \frac{1}{1+}\ \frac{1}{5+}\ \frac{1}{5+}\ \ldots\ldots\ldots$$

The successive convergents are 1/976, 10/9761, 31/30,259, 41/40,020 etc. Of these, our author has taken 10/9761, as being sufficiently simple and accurate. (Incidentally, this gives the justification for giving the corrected reading *ekartusaptanava*). By taking this fraction for use, for every S-day, 72,43,86,353/70,70,71,68,0000 − 10/9761 = 1,83,91,633/(7,07,07,16,80,000 × 9761) intercalary month is lost, i.e. in every period of 107 solar years, containing 107 × 360 S-days, the above fraction multiplied by 107 × 360 is lost, which reduces to (1 + 1214/6,54,696)/9761 = (1 + 1/550)/9761 very nearly (or exactly, if possibly 32′ given above is a correction to the nearest minute). So this also

should be included for greater accuracy and it can be done by an appropriate addition in the S-days, by the proportion: If 10/9761 intercalary month is got for one S-day, by how many S-days is (1 + 1/550)/9761 intercalary month got? Thus we get S-days equal to, (1 + 1/550)/9761 ÷ 10/9761 = (1 + 1/550)/10 = $\frac{1}{10} + \frac{1}{10} \times \frac{1}{550}$. This is for every 107 years, and so, for every 107 years, 1/10 S-day has to be added for greater accuracy in getting the intercalary months and for every 550 such additions one more tenth is to be added, which is the instruction given. (This is the reason for our giving as the correct reading, *'tithidaśamāṃśam* where *tithi* according to the context means S-day).

Now we proceed to explain the part of the formula relating to the elided days. We got before that there are 11,40,37,61,190 elided days in a period of 7,28,80,32,70,590 lunar *tithis* or simply *tithis*. Cancelling out a factor 30, we have 38,01,25,373 elided days for 24,29,34,42,353 *tithis*. So, to obtain the elided days for *tithis* gone we have the proportion, 24,29,34,42,353: 38,01,25,373 :: *tithis* gone: elided days during the period, i.e. elided days = *tithis* gone × 38,01,25,373 ÷ 24,29,34,42,353. The multiplying fraction 38,01,25,373/24,29,34,42,353 can be expressed as a continued fraction thus:

1	38,01,25,373	24,29,34,42,353	63
1	3,45,81,519	34,55,43,854	9
	2,71,336	3,43,10,183	126
	....	....	

$$38{,}01{,}25{,}373/24{,}29{,}34{,}42{,}353 = \frac{1}{63+}\;\frac{1}{1+}\;\frac{1}{9+}\;\frac{1}{1+}\;\frac{1}{126+}\;\ldots\ldots\ldots\ldots$$

The successive convergents are 1/63, 1/64, 10/639, 11/703, 1396/89217 etc. Of these, our author has taken 11/703 (note that this is the same as that of the *Romaka*) as being enough for a first approximation. By taking this, 38,01,25,373/24,29,34,42,353 − 11/703 = 2,71,336/(24,29,34,42,353 × 703) elided day is left out for every *tithi*. In the period of 245 years, given in the rule, there are, from the constants given before, 7,28,80,32,70,590 × 245 ÷ 1,96,40,88,000 *tithis*. So in this period the left out elided day is {2,71,336/24,29,34,42,353 × 703} × {72,88,03,70,590 × 245 ÷ 1,96,40,88,000} = 16,61,933/(16,36,740 × 703). This can be included in the formula by making a proportionate change in the *tithi* thus: To get 11 elided days we have to take 703 *tithis*, to get the elided days left out in 245 years, we must take *tithis* equal to 703 × 16,61,933 ÷ (16,36,740 × 703 × 11) = 16,61,933 ÷ (16,36,740 × 11) = (1 + $\frac{25{,}193}{16{,}36{,}740}$)/11 = 1/11 + 25,193/(16,36,740 × 11). In this the first term 1/11 is given by the instruction to add an eleventh of a *tithi* every 245 years. The second term does not agree with the instruction to omit adding one eleventh for every addition of 2,03,279 elevenths. This may be due to several reasons. It may be that the mean motion for 3031 days is given to the nearest minute, and small as this is, it can affect the value of the correction which itself is very very small. Or the *Pauliśa* Moon is slightly different from the *Vāsiṣṭha* Moon, which we have assumed for the *Pauliśa*. Or there is some error in the text here. We must be satisfied with the other and more important items of agreement. It must be remembered here that TS have omitted even the translation of these two verses, as a hopeless task.

Now we proceed to examine the *kṣepas* used in the formula. At the time of Epoch, the *Vāsiṣṭha* mean Moon is $11^r 25° 6'$ (vide II.3). As done before, we assume this for the *Pauliśa* also. The *Pauliśa* mean ('mean' here is the assumed mean) Sun is $11^r 29° 44'$ (vide III.1). From these we can see that the mean new moon will occur after 23 *nāḍikās*. From the *kṣepa* for elided day given, 444, we can see that the end of the Amāvāsyā occurs, before the beginning of the next day by $444 \times 59/703 =$ 37 *nāḍikās*, i.e. 23 *nāḍikās* after the Epoch, and thus there is agreement. (This shows that the reading *'trikṛtadināny avamasaṅkṣepaḥ'* is correct).

We shall examine the *kṣepa* for the intercalary month. The *kṣepa* given is 698. Dividing by the given divisor, 9761, we see that at the time of Epoch there is a fraction of 698/9761 intercalary month left. As the fraction of intercalary month is the interval from new moon to the next ending moment of the solar month, we get that 698/9761 synodic month = 2 days and 6½ *nāḍikās* after new moon, the Sun enters the next *rāśi*, here Meṣa. We have seen that the mean new moon itself falls 23 *nāḍikās* after Epoch. Therefore we get that the Sun enters Meṣa 2 days 6½ *nāḍikās* + 23 *nāḍikās* = 2 days 29½ *nāḍikās* after Epoch. The proper mean Sun computed for Epoch is $11^r 27°$ $33'$ (vide III. 1-3), i.e. after traversing $2° 27'$, i.e. after 2 days 29½ *nāḍikās*, the Sun will enter Meṣa. This is the same as what we have computed from the *kṣepa* 698, and thus it is verified.

Perhaps the reader has noted here that in the verification of the *kṣepa* for elided day we have used the assumed mean Sun (written 'mean' Sun) at Epoch and of the *kṣepa* for intercalary month, the proper-mean-Sun at Epoch. Is it proper, he may ask? Logically it is not. But, after all, what we want is to get the Days from Epoch correctly. If, by this shift, the rule is simplified, without sacrificing accuracy, then there is no harm in having recourse to it, thinks the author. We have already said that the mean Sun and Moon can alone be taken in framing the rule here. What we have called above, the 'proper-mean' is really the mean and so that part is all right. If here the assumed mean Sun is used, which is *practically* the true Sun at Epoch, an intercalary Vaiśākha will be falling immediately which will necessitate giving a *kṣepa* almost equal to the divisor 9761 and cause a lot of trouble. So the author has done what is only proper here. Then why not use the mean Sun to get the elided day *kṣepa* also? The *Pauliśa*, in giving its peculiar method, has assumed the beginning of the true Solar year as that of the mean Solar year, so that the true Sun at that point is assumed as the mean Sun. Our author has taken it as it is given and computed the *kṣepa* for the elided day accordingly, for, as we have already said, there must be the check by comparing the weekday and that will take care of everything. Or, some astronomer, unaware of the illogicality, has handled the *kṣepa*. While TS omit to translate the verses 11-13, merely stating that the details are obscure (Tr. p.5), NP change several ms. readings, *daśamāṃsa* to *daśāṃsa*, *pañcakṛtadvisammitāḥ* to *pañcatanudvid-vimitāḥ*, *ekīkartum* to *eka ṛtu*, without getting anywhere near the correct sense.

[सौर-रोमकयोः रवि-चन्द्रयुगम्]

वर्षायुते 'धृति'घ्ने 'नववसुगुणरसरसाः' स्युरधिमासाः |
सावित्रे 'शरनवखेन्द्रियार्णवाशाः' तिथिप्रलयाः || १४ ||
रोमकयुगमर्केन्द्वोर्वर्षाण्या'काशपञ्चवसुपक्षाः' |
'खेन्द्रियदिशो'ऽधिमासाः 'स्वरकृतविषयाष्टयः' प्रलयाः || १५ ||
युगवर्षमासपिण्डं रविमानं साधिमासकं चान्द्रम् |
अवमविहीनं सावनमैन्दवमब्दान्वितं त्वार्क्षम् || १६ ||

Yuga of the Sun and the Moon (Romaka and Saura)

14. In the *Saura Siddhānta,* a period (actually the minor *yuga*) of 1,80,000 solar years contains 66,389 intercalary months and 10,45,095 elided days.

15. The luni-solar *yuga* of the *Romaka Siddhānta* consists of 2850 solar years. In this period, there are 1050 intercalary months and 16,547 elided days.

16. The solar years in the *yuga* multiplied by 12 gives the solar months in the *yuga*. The solar months plus the intercalary months are the synodic months in the *yuga*. The *tithis* got by multiplying the synodic months by 30 reduced by the elided days, are the civil days, (i.e. days) in the *yuga*. The civil days plus the solar years are the sidereal days in the *yuga* (or the synodic months plus the solar years are the Moon's revolutions in the *yuga*).

Example 3. Give the revolutions of the Sun and the Moon, the civil days etc. in a yuga (minor) of the Saura Siddhānta.

There are 1,80,000 solar years in the *Saura* minor yuga, and as a solar year is the period of revolution of the Sun, there are 1,80,000 solar revolutions in the *yuga*. Multiplying the solar years by 12, the solar months in a *yuga* are 12 × 1,80,000 = 21,60,000. The synodic months are solar months *plus* intercalary months = 21,60,000 + 66,389 = 22,26,389. The *tithis* are 30 × 22,26,389 = 6,67,91,670. The (civil) days are, *tithis* – elided days = 6,67,91,670 – 10,45,095 = 6,57,46,575. The sidereal days are, civil days *plus* solar years = 6,57,46,575 + 1,80,000 = 6,59,26,575. The lunar revolutions are, synodic months + solar years = 22,26,389 + 1,80,000 = 24,06,389.

Example 4. Give the revolutions of the Sun and the Moon, the civil days etc. in the Romaka yuga and the time of revolution of each, etc.

Sun's revolutions = solar years = 2850. The solar months are, 12 × 2850 = 34,200. The synodic months are, 34,200 + 1050 = 35,250. The *tithis* are, 30 × 35,250 = 10,57,500. The civil days are, 10,57,500 – 16,547 = 10,40,953. The lunar revolutions are, 35,250 + 2850 = 38,100. Dividing the days in the *yuga* by the solar revolution, the time taken for the one revolution, i.e. the solar year is, in days etc. 10,40,953 ÷ 2850 = 365-14-48. Dividing the days by the synodic months, the period of synodic revolution (month) got is in days, etc. 10,40,953 ÷ 35,250 = 29-31-50-5-37. Dividing the days by the lunar revolutions, the time for one revolution got is, in days etc. 10,40,953 ÷ 38,100 = 27-19-17-46.

The following points should be noted. The *Romaka Siddhānta*, now extant, agrees with the *Modern Sūrya Siddhānta* in its constants like the period of the *yuga*, the number of revolutions of the planets in the *Yuga* etc. But the *Romaka Siddhānta* condensed by our author is quite different and seems to

14a. B1. धृतिपे; B2. धृतिधे
b. A2. ०गुणा०
c. A1. ०न्द्रिर्णवाशाः; D. [नवकेन्द्रिया०]
c-d. B1.2. खेन्द्रिया-gap शास्तिथि
15a. B2. युग्मे for युगे
B1.2. मर्क्कैन्दो;
b. B1.2. पञ्चयेस्तु (B2. वस्तु) पक्षाः
d. A1.2. स्वकृत; B1. स्यात्कृत; B2. स्यकृत
B1.2. क्रियाष्टयः A1. ष्टयप्र; A.2. ष्टया प्र
16. Quoted by Ulpata on BS 2, p.29
a. B1.2. युगवर्षणं सपिण्डं
b. A1.2. साधिभासकं
d. A1.2. C.D. चार्क्षम्; B1.2. तार्क्षम्

be lost. Therefore we cannot determine whether the period of 2850 years mentioned here is the actual *yuga* of the original *Siddhānta* or a minor *yuga* (i.e. a fraction of it in whole years) given for convenience. Patently, the solar year given here is tropical and agrees with the value given to it by the ancient Greeks, like Ptolemy II and Herodotus. It is so with the duration of the synodic month also. Reducing the number of solar years and intercalary months in the *yuga* by the factor, 150, we see that there are 7 intercalary months in a period of 19 years or 228 solar months, which is the wellknown Metonic cycle. From all this we can conclude that this *Siddhānta* is from a Greek source.

In the case of the *Saura*, the period of 1,80,000 years given here is certainly a minor *yuga* of the original *Saura*, for by multiplying this by 24 we get the number of years in the *yuga* of the original, viz., 43,20,000 years. From this we can infer that in the *yuga* of the original there are 1,80,000 × 24 = 43,20,000 solar revolutions, 6,57,46,575 × 24 = 1,57,79,17,800 civil days and 24,06,389 × 24 = 5,77,53,336 lunar revolutions. We have already mentioned that all these agree with the *Ārdharātrapakṣa* of Āryabhaṭa given in the *Mahābhāskarīya*, with the *Khaṇḍakhādyaka* which is based on the *Ārdharātrapakṣa* and with the *Pauliśa* quoted by Bhaṭṭotpala in his commentary on the *Bṛhatsaṃhitā* but not with the Modern and well-known *Sūrya Siddhānta*.

Now what is the purpose of our author in giving the *yuga*-elements of these two *Siddhāntas* alone? Our author expects that, like the *Pauliśa*, the *Saura* also would be used for a long time. So, if the time taken is far from the Epoch, he expects the reader to make his own rule, taking the elements given here, following the method of the *Romaka*. In the case of the *Romaka* itself, the accumulation of error in the rule can be prevented by deducting multiplies of 2850 years from the years gone from Epoch and doing the work with the small number of years left. Also, in the case of both, we can use the elements given here to check the constants given in later work, for mistakes.

We shall now explain the rules of verse 16, indicating the Sun's revolution as R, the Moon's r, the synodic months m, the intercalary months i, the elided days e, the Tithis t, the civil days d, and the sidereal days n.

(i) We shall explain the synodic month and derive the relation between the synodic months and lunar revolutions in the *yuga*. The synodic month is the interval between two consecutive conjunctions of the Sun and the Moon. In the *Yuga* the Moon makes r revolutions and, therefore, in one day makes r/d revolution. In the same way, the Sun makes R/d revolution. In one day they move apart by $\frac{\mathrm{r}-\mathrm{R}}{\mathrm{d}}$ revolution. When the separation equals one revolution they are in the next conjunction. The period of separation equal to one revolution, in days $= 1/\frac{(r-R)}{d} = \frac{d}{(r-R)}$, which is the length in days, of the synodic month .... (1)

For $d/(r - R)$ days, there is one synodic month; for d days (i.e. the days of the *yuga*) there are $d/\{d/(r-R)\} = r - R$ synodic months, i.e. $r - R = m$, $r = \mathrm{m} + \mathrm{R}$.........(2); i.e. adding the Sun's revolutions to the synodic months, the lunar revolutions are obtained.

(ii) The explanation of the intercalary month and its relation to the synodic month: The synodic months, Caitra etc. are those that end in the solar months Meṣa etc., and there is normally one to one correspondence between the two sets. But as the synodic month is shorter than the solar it successively ends earlier and earlier in the solar and when it happens that the synodic month ends so early in the solar that another synodic month also ends within the same solar, obviously it has to be left out of reckoning if the correspondence between the set Caitra etc. with the set Meṣa etc. has to be maintained. This is the *Adhikamāsa* or intercalary month.

Now, in one solar year there are 12 R solar months. As there are R years in the *yuga*, there are 12 R solar months in the *yuga*. Therefore the length of a solar month in days = $d/12R$. The length in days of a synodic month, already derived, = $d/(r-R)$. Therefore in every solar month the end of the synodic month (i.e. the new moon) occurs earlier by $d/12R - d/(r-R) = d(r-13R)/12R(r-R)$. When this is equal to one synodic month and gets immersed in the solar, then one intercalary month happens, and the time for this to happen is, in terms of solar months, $d/(r-R) \div \{d(r-13R)/12R(r-R)\} = 12R/(r-13R)$. Therefore, in the *yuga* containing $12R$ solar months the number of intercalary months $i = 12R/\{12R/(r-13R)\} = r - 13R\ (r-R) - 12R = m - 12R$. Therefore $12R + i =$ m...... (3), i.e. the solar months + the intercalary months give the synodic months.

(iii) We shall explain the occurrence of elided days and derive their number: The length of a *tithi* is a little less than a day and so every day the *tithi* occurs earlier and earlier in the day, until the time so accumulated becomes equal to one *tithi* and gets immersed in the day, with the result that the correspondence, one *tithi* to one day, is broken. Such *tithis* are left out by reckoning and are called 'submerged *tithis*' or 'elided days'. Now, as there are in the *yuga d* days and *t tithis,* the duration of one *tithi* = d/t. In one day, the *tithi* falls earlier by $1 - d/t$ day. This accumulates to one *tithi* in $d/t \div (1 - d/t) = d/(t-d)$ days, which is the time for one elided day to happen. Therefore, the number of elided days happening in a Yuga = $e = d/\{d/(t-d)\} = t - d$. Therefore $d = t - e$ ..... (4), i.e. deducting the elided days from the *tithis* we get the days.

(iv) We shall explain the sidereal day and derive the number of sidereal days in the *yuga*. The time taken by the stellar sphere to move (apparently) one round, is the sidereal day. But the day, i.e. the civil day, is related to the apparent diurnal movement of the Sun, from sunset to sunset, from sunrise to sunrise, from midnight to midnight etc. As there are n sidereal days and d days in the *yuga*, in one sidereal day the Sun makes d/n revolution. Therefore in one sidereal day he lags behind by $1 - d/n = (n-d)/n$, revolution. This lagging behind is due to the Sun's eastward motion in the Sky and its magnitude is the Sun's motion in terms of revolutions during a sidereal day. This is equal to R/n. Therefore, $(n-d)/n = R/n$. Therefore, $(n-d) = R$. Therefore $n = R + d$ .....(5), i.e. adding the solar years to the days, we get the sidereal days. Thus all the rules of verse 16 have been explained.

[वर्षाधिपः]

'मुनियमयमद्वि'युक्ते द्युगणे 'शून्यद्विपञ्चयम'भक्ते ।
प्रति(राश्य) 'खर्तुदहनै' र्लब्धं वर्षाणि यातानि ॥ १७ ॥
तानि प्रपन्नसहिता'न्यग्नि'गुणा'न्यङ्घ्रि'वर्जितानि हरेत् ।
सप्तभिरेवं शेषो वर्षाधिपतिः क्रमात् सूर्याद् ॥ १८ ॥

Lord of the year

17. Add 2227 to the days from Epoch, divide out by 2520 and take the remainder. Set this in 3 places. In one place divide the remainder by 360 and take the quotient.

18. Add 1, multiply by 3, deduct 2 and divide out by 7. The remainder counted in the order Sun (Ravi), (Moon, Bhauma, Budha, Guru, Śukra and

Manda) is the Lord of the year (in which the taken day falls) (i.e. If Q is the quotient taken, the number to be divided out by 7 is equal to $(Q + 1) \times 3 - 2$).

Example 5. The days from Epoch is 3479. Give the Lord of the year.

Adding the *kṣepa* to the days given, $3479 + 2227 = 5706$. Dividing out by 2520, the remainder is 666. Dividing this by 360, the quotient obtained is 1. $(1 + 1)3 - 2 = 4$. The fourth from the Sun, Budha is the Lord of the year.

The processes mentioned here are explained thus: At the moment 2227 days before Epoch, beginning Sunday, the days for calculating the Lord of the year etc. began and, as for the first day from that point of time, for the first month and the first year also beginning from that moment, the Lord was the Sun. To find these Lords for any time, the days from this point must be found and as the Epoch is 2227 days from this point, the days required are got by adding 2227 to the days from Epoch. For the purpose of calculating the Lord of the Year, the *sāvana* year comprising 360 days is used by our author and the Lord of the first day of the *sāvana* year is the Lord of the year. In the same way, to calculate the Lord of the month, the *sāvana* month of 30 days is used, the Lord of the first day of the month being the Lord of the month also. Now, as 2520 is the least common multiple of 360, 30 and 7, after each period of 2520 days, these Lords are repeated in the same order. Hence the instruction to divide the days out by 2520 and take the remainder alone. This remainder is set in 3 places to find the Lords of the year, the month and the day. Taking the remainder of the days, the Lord of the first year is that of the first day, the Lord of the second year is that of the first day in the next year, i.e. of the 361st day, i.e. that of the $(358 + 3)$th day, i.e. that of the day three days after; the Lord of the year next to that is that of the day 6 days after that of the first and so on. Thus, the Lord of the nth year is that of $(n - 1)3 + 1$, i.e. that of $n \times 3 - 2$. If Q is the number of years gone, then $n = Q + 1$, and the Lord is that of $(Q + 1)\,3 - 2$, which is the rule given. As the same Lord is repeated by the addition of multiples of 7, by casting out 7 we get the same and hence the instruction to cast out seven and take the remainder alone.

Dividing the days into *sāvana* years and giving the Lord of the first day of the year as the Lord of the year is peculiar to our author. For others the Lord of the first day of the *saura* year and for yet others that of Caitra Śukla Pratipad is the Lord of the year. Some give two Lords.

There is a flaw in the derivation of this rule by M.M. Sudhakara Dwivedi (vide page 6 of his Commentary). It has been hidden by another mistake made by him, viz., adopting the reading '*aṅghri*' (= 2) but using the reading '*abdhi*' (= 4) in the derivation. The reading *pratirāśca* is really *pratirāśya*. Both NP and TS take the reading *pratirāśi* and moreover, S gives it the incorrect meaning *śeṣam*, 'remainder'.

17-18. Quoted by Utpala on BS 2.2, pp. 30-31.
17a. B2.गुनियम
c. A1.2.प्रतिराश्च; B1.2.गतिराश्च; C.D.प्रतिराशि
A1.2.दहनै ल०
d. A1.2.पाताति

18b. A1.2.गुणान्यब्धि; B1.गुणान्याघ्रि; B2.गुणान्यघ्रि;
D.U.गुणान्यश्वि
A1.2.वर्जिता हरेत्
c. e.शेषं
d. A1.वपाधिपतिः; A2.वषाधिपतिः;
B1.2.वर्षाधिपति क्र०

[मासाधिपः]

त्रिंशद्भक्ते मासाः प्रपन्नसहिता द्विसंगुणा [व्येकाः] |
सप्तोद्धृतावशेषे मासाधिपतिस्तथैवार्कात् || १९ ||

Lord of the Month

19. Take the remainder set apart (as mentioned in verses 17-18), divide by 30 and take the quotient. Add 1, multiply by 2 and deduct 1. The remainder, after dividing out by 7, is the Lord of the month, counted from the Sun.

The rule is $(Q + 1)2 - 1$, where Q is the quotient taken.

Here in the place of the reading '*kāryāḥ*' accepted both by TS and NP, we have adopted the reading *vyekāḥ*, given by Bhaṭṭotpala in his *Br. Sam.* commentary, as being the correct one and as necessary here. Also in the place of *prapanna* Bhaṭṭotpala reads *pratipada*. Whatever be the reading here, we want the meaning '1'.

The rule is derived thus: As mentioned before for the Lord of the year, to get the Lord of the month the days are divided into *sāvana* month of 30 days duration and the Lord of the first day of the month is the Lord of the Month. Thus the Lord of the very first day, viz. the Sun is the Lord of the first month. As the days in the month, 30, divided out by 7 leaves the remainder 2, the Lords of the successive months are those of 2, 4, 6 etc. days after that of the first month, i.e. the Lord of the nth month is given by $(n - 1)2 + 1 = n \times 2 - 1$. As n is the current month, it is equal to $(Q + 1)$. Therefore $n \times 2 - 1 = (Q + 1)2 - 1$, which is divided out by 7 gives the Lord of the month.

Here too the derivation of M.M. Sudhakara Dwivedi is wrong (vide his commentary on the verse. p. 6). The translation of both TS and NP are incorrect for having taken the reading *kāryāḥ* for *vyekāḥ* ('deduct 1'), not realising which NP complain: "The text's (I.19) 'increase the (resulting) months by the current one' should be replaced by 'discard the fractional part of the current (month)' (Pt. II, p. 13, footnote). On verses 17-19, K.S. Shukla has a detailed note in his paper, 'The *PS* of VM (2)' *Gaṇita*, 28 (1977) 99ff."

Example 6. For the same day as given in Ex. 5 give the Lord of the month.

The remainder set apart (in the *Ex. 5)* is 666. Dividing by 30, the Quotient, Q, obtained is 22. $(22 + 1)2 - 1 = 45$. Dividing out by 7, the remainder is 3. Hence, the third from the Sun, viz. Bhauma is the Lord of the month.

[होराधिपः]

सप्तोद्धृते दिनेशः त्रिगुणेऽ(ध्येके) [युते च] होराभिः |
(पञ्चघ्ने) सप्तहृते विज्ञेयः कालहोरेशः || २० ||

19. Quoted by Utpala on BS 2. p.31.
19a. B1.2. प्रभवसहिताः; U. प्रतिपत्सहिताः
b. A1.2. B1.2. C.D. कार्याः for व्येकाः
c. B1.2. सप्तोधृता
U. शेषो
d. B1. वाध्यात्

Lord of the Horā

> 20. Take the remainder set apart in verses 17-18. Divide out by 7 and the remainder is the Lord of the Day, counting from the Sun. Take *this* remainder, multiply by 3, add 1, and add also the number of *horās* (i.e. the hours) counted from the beginning of the day, (i.e. the previous sunset) inclusive of the *horā* in which the taken moment falls. Multiply by 5 and divide out by 7. The remainder, counted from the Sun, gives the Lord of the Horā.

If the Lord of the day is dth from the Sun and the time taken falls in the hth *horā*, then the number for the Lord of the Hora is $(3d + 1 + h) \times 5$.

It should be noted here that the *horā*, h, is counted from sunset, because the time of Epoch is sunset and the day is said to commence there.

The derivation of the two rules: The rule for the Lord of the Day is obvious for the order of the Lords, Sun Moon, Bhauma, etc. is meant to be the order of the Lords of the weekdays, Sunday, Monday, etc. The rule for the Lord of the *horā* is derived thus: From the *Śāstra* we learn that the Lord of the *horā* beginning at sunrise is the same as the Lord of that day. The Lord of the *horā* beginning Sunday, i.e. of the *horā* just after sunset of Saturday, (i.e. Mandavāra), is Budha, since the Lord of the *horā* after sunrise on Mandavāra is Manda and the successive Lords of the *horās* are the fifth after each, i.e. the sixth counting from each. (vide the next verse, 21). Budha is the 4th in order. After this if $(n - 1)$ *horās* are gone, the Lord of the nth *horā* is given by $(n - 1)5 + 4$. Let us find the Lord of the *horā* for the h-th *horā* of the d-th day. This is $\{(d-1)24 + h\}$th *horā*. Therefore the Lord of the *horā* is, substituting this for n in the above formula, $\{(d - 1)24 + h - 1\} 5 + 4 = (24d + h - 25) 5 + 4 = (21d + 3d + h + 1 - 26) 5 + 4 = (3d + 1 + h)5 + 4 + 5 \times 21d - 5 \times 26 = (3d + 1 + h) 5 + 105d - 126 = (3d + 1 + h)5 + 15d \times 7 - 18 \times 7$. As no change in the Lord happens by adding or deleting multiples of 7, this reduces to $(3d + 1 + h)5$, which is the rule given. (Here too the derivation of M.M. Sudh. is wrong. Let the readers examine his commentary.) The acceptance of the expression *vyeka* in place of the ms. reading *'dhyeka* both by TS and NP has rendered their translations incorrect.

Example 7. (a) Who is the Lord of the Day, for the day given in Ex. 5? (b) On the same day, who is the Lord of the Hora, fifth after sunrise?

(a) The remainder set apart according to verses 17-18 is 666. Dividing out by 7, the remainder left is 1, i.e. the Lord of the Day is the Sun.

(b) In the example, $d = 1, h = 5 + 12 = 17$ (because h is counted from the beginning of the day, i.e. the previous sunset). Substituting, $(1 \times 3 + 1 + 17)5 = 105$. Casting out 7, the remainder is 0 or 7 and the 7th from the Sun, Manda is the Lord of the *horā*.

वर्षाधिपश्चतुर्थो मासाधिपतिस्ततो योऽन्यः |
होराधिपश्च षष्ठो निरन्तरं दिवसनाथश्च || २१ ||

20. Quoted by Utpala on BS 2, p.34.
20a. B1.2.सप्तोधृते
b. A1.2. B1.2.०ध्येकश्चहोरादिः; C.D. U.त्रिगुणो व्येको युतश्र्च होराभिः
c. C.D. U.पञ्चघ्न; B1.सप्तहते; B2.सप्तहुते; C.D. U.सप्तहतो
d. A1.2.विज्ञेया; B1.विज्ञेय A1.2.कालहोरेशाः; B1.कायहोरेषः; B2.कायहोरेशः

21. The fourth counted *from* the Lord of any year is the Lord of the year next to that. The third *from* the Lord of any month is the Lord of the month next. The sixth *from* the Lord of any *horā* is that of the next *horā*. The Lords of the day come consecutively, in the order given.

This the explanation: It has been said that the Lord of the year is that of the *sāvana* year of 360 days, coming one after another. The Lord of the first day of the year is the Lord of the year and the Lord of the 358th day is the same. The Lord of the next year is that of the 361st day, which is the fourth counting from 358. Thus the Lord of the next year is the fourth counting from that of the previous year. In the same way, the Lord of the next (*sāvana*) month is that of the 31st day, counted from the first day of the previous month. The Lord of the 29th day is the same as that of the first. The 31st day is the 3rd counting from the 29th. Therefore, the Lord of the 31st day, i.e. the Lord of the next month, is the third from that of the previous month. The Lords of the *horās* come in the order, Manda, Guru, Bhauma, Ravi, Śukra, Budha and Soma, which is the descending order of the distances of their orbits. The planet next in this series, who is the Lord of the next *horā*, is the 6th in the series given by our author, and hence the statement that the sixth from the previous is the Lord of the next *horā*. That the Lords of the day come consecutively is obvious, for the series Ravi, Soma, Bhauma, etc. is given in the very order of the Lords of the day.

One thing must be said here. The author has taken the Lords in the arbitrary order Ravi, Soma etc. as it is well known by means of the week-days we are using in our day-to-day affairs. But the order of the Lords of the *horā*, viz. Manda, Guru, etc. based on their distances is fundamental and given by the *Śāstras*, which give the Lord of the week-day itself as being the same as the Lord of the first *horā* after sunrise on that day, taking the Lord of the *horā* as known. Taking this order we can make the following statements: The Lord of the next day is the 4th as counted from that of the current day, the Lord of the next month is the 7th counted from that of the current month (or, which is the same, the one previous to that of the current month) and the Lord of the next year is the third counted from that of the current year.

वर्षे यद्यस्य फलं मासे च मुनिप्रणीतमालोक्य |
[तत्तद्वृत्तै]र्वक्ष्ये होरातंत्रोत्तरविधाने || २२ ||

22. Consulting the works of Sages, I shall tell in my future work following the *Horā-Tantra*, the predictions, viz. which results will flow during the reign of which Lord of the year or Lord of the month.

There is a gap in this verse in every manuscript, *tattadvṛttaiḥ* being missing. So we have adopted the reading of Bhaṭṭotpala in his *Bṛ. Sam.* commentary which is full.

21. Quoted by Utpala on BS 2, p.35.
21a. A1.2. B1. चतुर्थे
b. A1.2. पतिस्तथानतो; B1.2. पतिस्तथा ततो; C.D. पतिस्तथा [तृतीयोऽन्यः]
c. B1.2. होराधिपतिश्र्च. A1.2. B1.2. षष्टो
d. A1. दिवनाथश्च; U. दिवसनाथः स्यात्

22a. B3. Commences with this verse. B1.2.3. वर्षे यस्य फलं
b. B2. मासे वा
c. A.B. on. तत्त द्धृत्तैः; C. [तत्तत्फलं च] A1.2. B1.2. वक्षे
d. B1. होम and B2. होरां for होरा A1. °त्तविधानैः; B2. तविधानै; B. विधानै

द्युगणे 'रूपा'भ्यधिके 'पञ्चर्तुगुणो'द्धृतेऽथ मासाः स्युः |
त्रिंशद्भक्ते शेषं ज्ञेयं राश्यंशकेन्द्राणाम् || २३ ||

कमलोद्भवप्रजेशौ स्वर्गः शस्त्रं (द्रुमान्नवासांसि) |
(कालानलाभ्ररवयः) शशीन्द्रगोनियतयः क्रमशः ||२४ ||

हरभवगुहपितृवरुणा बलदेवसमीरणौ यमश्चैव |
(वाक्) श्रीधनदौ (निरयो) धात्री (वेदाः) परः पुरुषः || २५

23-25. Add 1 to the Days from Epoch, divide by 365, take the remainder and divide this by 30. The quotient are the months gone. The remainder gives the Lords of the current degree in the current month. They are, corresponding to each degree, Kamalodbhava (Brahmā), Prajāpati, Svarga (Heaven), Weapon, Tree, Anna (Food), Residence, Kāla (Time), Agni, Abhra (Cloud), Sun, Moon, Indra, Cows, Niyati (Fate), Hara, Bhava, Guha, Manes, Varuṇa, Baladeva, Vāyu, Yama (the ruler of the World of the manes), Vāk (Goddess of Speech), Śrī (the Goddess of Wealth), Kubera, Hell, Earth, Vedas and the Supreme Being.

This matter must have been taken from the ancient *Saṃhitās* by our author and given here. For the purpose of giving the Lord of the degrees they must have divided the days into years of 365 days (why not the exact duration of the solar year, we cannot say) and the years into months of 30 days as can be inferred from the instruction. But then it comes to giving the Lord of not the degrees of the *rāśi* but that of each of the *sāvana* days in the *sāvana* month. For the 5 days left over at the end of the year it must be taken that the first 5 Lords are repeated.

Example 8. Give the Lord of the Degree of the rāśi for Days from Epoch 3479.

Adding one and dividing by 365, the remainder is 195. Dividing by 30, the remainder is 15. Therefore the fifteenth in the list, Niyati (Fate) is the Lord required.

Ed. Note: NP have identified verses 23-25 as relating to the Magas, emending the expression *māsās syuḥ* in verse 23 to *magābdāḥ syuḥ* and have correlated the 30 names enumerated in the verses with the lords of the 30 days in the month according to the Magan calendar. K.S. Shukla has studied these three verses in detail, noted that these names are enumerated also in the *Vaṭeśvara Siddhānta* (ch. I, sn.v, *vv*. 117 c-d, 118) and has traced the names to their Zoroastrian (Parsi) originals, as per the following Table, in his paper 'The *PS* of VM (2)', *Gaṇita*, 28 (1977) 99-116.

23a. A2.द्युगणो; B1-3कगणे
b. A2.पञ्चर्शु. A1.2. धृतेथ; B1.3. ध्वजेथ.
A1.2.मासा स्युः; D. [मगाब्दाः] स्युः
d. A1.2.वेन्द्राणां; B1.2.चन्द्राणां
24a. A1.2.कम्लोन्द्ववा; B1-3.कम्लोन्द्ववं; C.D.कम्लोन्द्ववः
A1.2.प्रजेसा; B1-3. C.D.प्रजेशः
b. A1.2.स्वर्ग्ये; B3.स्वर्यः; C.स्वर्गी; D.स्वर्गे
C.॰शश्चन्द्रमान्यवासांसि; D. [श] शास्तृरुद्रमन्युवसवः
A1.2.रुद्रमान्य; B1.2.रुद्रभान्य॰; B3.रुद्रन्तान्य॰
c. A1.2. B1.2. C.D.कमलानलान्तरवयः (B2.॰खं यः)
d. C.D.गोनिर्ऋतयः. B.हरत्रव
25a. A1.2.चरुणा; B1.वरुण; B3.वरुणां;
D. [भवगुरु] पितृ
b. A1.वलदेव; A.2.वलहेव A1.2.समीकरणौ
c. B1.3.प्राक् श्रीधनवौ । A1.2. B1.3. C.D.गिरयो
d. A1.2.वेधा; B1.3. C.D.वेधाः A.2.पुरः. A1.2.पुरूषः

Names of the 30 days of the Parsi months

Name in VM	Name in *Vaṭeśvara Siddhānta*	Zoroastrian (Parsi) name
1. Kamalodbhava (Lotus-born)	Brahmā	Ahurmazd (Lord God)
2. Prajeśa (Protector of creatures)	Prajāpati (Protector of creatures)	Bahman (Protector of creatures, Brahman)
3. Svarga (Heaven)	Dyauḥ (Heaven)	Ardibahesht (Holder of the keys of heaven)
4. Śastra (Weapon)	Śastra (Weapon)	Shahrivar (Lord of pure metal)
5. Druma (Tree)	Taru (Tree)	Spandarmad (Charitable)
6. Anna (Food)	Anna (Food)	Khurdad (Lord of festivals)
7. Vāsa (Residence)	Vāsa (Residence)	Amordad
8. Kāla (Yama)	Kāla (Yama)	Depadar (Associate of Ahurmazd)
9. Anala (Fire)	Agni (Fire)	Adar (Fire)
10. Abhra (Filled with water, Cloud)	Kha (Same as Abhra)	Avan (Waters)
11. Ravi (Sun)	Ravi (Sun)	Khurshed (Sun)
12. Śaśi (Moon)	Śaśi (Moon)	Mah (Moon)
13. Indra (God of rain)	Indra (God of rain)	Tir (Distributor of water)
14. Go (Cow)	Go (Cow)	Gosh (Cow)
15. Niyati (Destiny)	Niyati (Destiny)	Depmehr (Ahurmazd's associate)
16. Hara (Mihira, Sun)	Savitṛ (Sun)	Meher (Sun)
17. Bhava (Śiva)	Guha (Son of Śiva)	Sarosh (Protector of the living and the dead)
18. Guha	Aja (Unborn God)	Rashna
19. Pitṛ (Manes)	Pitṛ (Manes)	Farwardin (Farohars of the dead)
20. Varuṇa	Varuṇa	Behram (or Varenes)
21. Baladeva (Balarāma)	Hali (Balarāma)	Rām
22. Samīraṇa (Wind)	Vāyu (Wind)	Govad (Wind)
23. Yama	Yama	Depdin (Ahurmazd's associate)
24. Vāk (Speech)	Vāk (Speech)	Din
25. Śrī (Righteousness)	Śrī (Righteousness)	Ashisvang (Righteousness)
26. Dhanada (Kubera)	Dhanada (Kubera)	Ashtad (Aingel created by Mazda)
27. Niraya (Hell)	Niraya (Hell)	Asman (Sky)
28. Dhātrī (Earth)	Bhūmi (Earth)	Zamvad (Earth)
29. Veda	Veda	Marespand (Zarathustrian law and religion)
30. Paraḥ Puruṣaḥ (Supreme Being)	Parapuruṣa (Supreme Being)	Aneran (Endless lights of shining heaven)

[इति पञ्चसिद्धान्तिकायां वराहमिहिरविरचितायां
करणावतारो नाम प्रथमोऽध्यायः ॥] [1]

1. A.B.C.D. करणावतारः

Thus ends Chapter One, entitled 'Introduction of the Work', in the Pañcasiddhāntikā composed by Varāhamihira

Chapter Two

VĀSIṢṬHA-SIDDHĀNTA — PLANETARY COMPUTATIONS ETC.

२. द्वितीयोऽध्यायः
वासिष्ठसिद्धान्तः — ग्रहादिगणितम्

Introductory

Now follow the five *Siddhāntas*. Of these the *Vāsiṣṭha* is given first, as being the most primitive among the *Siddhāntas* that distinguish between true and mean motions, unlike the *Paitāmaha* which gives only the mean motion. For a detailed exposition of some of the verses see T.S.K. Sastry, 'The Vāsiṣṭha Sun and Moon', *JOR* 25 (1955-56) 19-41 and K.S. Shukla, 'The *PS* of VM(2)', *Gaṇita* 28 (1977) 99-116.

[स्फुटरविः]

'कृत'-'गुणमृतु'-युत'मेकर्तुमनु'हतं 'षड्यमेन्दु'भिर्विभजेत् |
'शशि-ख-ख-ख-यम-कृत-स्वर-नव-नव-वसु-षट्क-विषयो'नैः || १ ||

True Sun

1. Multiply the Days from Epoch by 4 and add 6. Divide this by 1461 (and take the remainder). Take from this, successively, the quantity 126, reduced by 1, 0, 0, 0, 2, 4, 7, 9, 9, 8, 6, 5 (i.e., the twelve quantities 125, 126, 126, 126, 124, 122, 119, 117, 117, 118, 120, 121). (The Sun's *rāśis*, Meṣa etc. are successively got.)

The direction is: Multiply the days by 4, add 6, divide by 1461 and take the remainder. From this first take off 125, and consider that Meṣa is gone. Then from what remains deduct 126 and consider Ṛṣabha is gone, and so on. The Sun is in the *rāśi* corresponding to the number which cannot be deducted on account of its being less than what is left over. Multiply what is left over by 30 and divide by what cannot be deducted. The position of the Sun in that *rāśi* is got, in degrees.

It is to be noted that even 'Days from Epoch' is not mentioned here but we take it as understood because every work of this sort requires it. It is not specifically mentioned that this rule is for computing the true Sun but we can infer it from the quantities here given and the work asked to be done. Even the work is not clearly and completely given. But knowing what the author is about, we can see what is wanted to be done. TS have refrained from interpreting this, as an impossible task.

1a. A1. कृतगुणयषमृतु; A2. कृतगुणपयमृतु;
BC. कृतगुणषड्ऋतु

b. D. वियुजेत्

a-b. A3. मैकर्तु

c-d. A.B.C. खरकृत for कृतस्वर

The text here *svarakṛta* has been changed into *kṛtasvara* by interchanging the words, as the nature of the work requires it and as this kind of transposition is sometimes found in manuscripts. It is impossible that the *Siddhānta* itself has made this mistake, not noticing the ascending nature of the series in this part.

Next, we are in doubt here about the time of the day (like sunrise, sunset, noon or midnight) for which the Sun is here given. One may think that because no time is mentioned here, not even the instruction to take the 'Days from Epoch', one is expected to take the Days of the *Romaka* or the *Pauliśa* and with its own time of sunset at Yavanapura, i.e. thirty-seven *nāḍis* twenty *vināḍis* from sunrise at Ujjain. But later, in dealing with the Romaka itself and with the *Saura*, the author gives different times of day for different computations (vide VIII.5, IX.1, XVI.1) and hence this doubt. It is likely that the *Vāsiṣṭha* Sun and Moon are given for sunrise at Ujjain, as we shall show while dealing with the Moon.

Another point to be noted is this. The rule gives the 'True' Sun directly, without giving the 'Mean' Sun. This is possible because this *Siddhānta*, like the other *Siddhāntas* of the period like the *Āryabhaṭīya*, has taken the apogee of the Sun as fixed and, so, for a given day in the solar year there, is a given anomaly with a given equation of the centre, which means a given true Sun. (It is so with the *Vākyakaraṇa* also, which follows the *Mahābhāskarīya* based on the *Āryabhaṭīya*, with this difference that here the days for fixed intervals of the true Sun is given, while in the *Vākyakaraṇa* the days for the Sun and the Sun for the days, both are given.)

The rule is explained thus: In this *Siddhānta* the solar year consists of 365 ¼ days, (like the Julian year), i.e. of 1461 quarter-days. For convenience of computation, the Days from Epoch are also converted into quarter-days. According to this *Siddhānta* the true solar year began, i.e. the true Sun was at the first point of Meṣa, 1 ½ days, i.e. 6 quarter-days, before Epoch. So 6 is added to the quarter-days from Epoch to give the true Sun from the beginning of Meṣa. As after periods of 365 ¼ days, i.e. 1461 quarter-days, the Sun returns to the first point of Meṣa, we can divide the quarter-days out by 1461 and take the remainder alone to find the Sun, i.e. its position from the beginning of Meṣa. Now this *Siddhānta* has found empirically that the true Sun traverses Meṣarāśi in 31 ¼ days, i.e. 125 quarter-days, Ṛṣabha-rāśi in 31 ½ days, i.e. in 126 quarter-days and so on. Thus in 125 + 126 + 126 + 126 + 124 + 122 + 119 + 117 + 117 + 118 + 120 + 121 = 1461 quarter-days the Sun traverses all the twelve *rāśis* and reaches Meṣa again. That these numbers add upto 1461, and 1461/4 = 365 ¼, the days of the year, is proof of the correctness of our interpretation of the rule. Thus we see that the solar months Meṣa etc. contain each 31 ¼, 31 ½, 31 ½, 31 ½, 31, 30 ½, 29¾, 29 ¼, 29 ¼, 29 ½, 30 and 30 ¼ days, respectively. It can be seen that these fairly agree with what is given by the other *Siddhāntas*.

Thus if 125 quarter-days are left over in the year the Sun has traversed Meṣa, if 125 + 126 are left over, it has traversed Meṣa, Ṛṣabha etc. It is obvious that its position within a *rāśi* is to be found by the proportion: If 30° are for the quarter-days of the *rāśi*, how many degrees for the quarter-days ultimately left over.

Example 1.(a). Days from Epoch 4246. Find the true Sun. (b) Find the true Sun for zero day.

(a) Days converted into quarter-days = 4 × 4246 = 16,984. Adding 6 we get 16,990. Dividing out by 1461, the remainder is 919. Deducting 125, 794 is left over; Meṣa is gone. Deducting 126, 668 is left over; Ṛṣabha is gone. Deducting 126 again, 542 is left over; Mithuna is gone. Deducting 126 for Karkaṭa, 416 is left over. Deducting 124 for Siṃha 292 is left over. Deducting 122 for Kanyā,

170 is left over. Deducting 119 for Tulā, 51 is left over, in Vṛścika, i.e. 51 117 of Vṛścika is gone, i.e. 30 × 51/117 degrees = 13° 5′. Therefore the true Sun = 7^r 13° 5′.

(b) For 0 day, 0 + 6 = 6, quarter-days. 30° × 6/125 = 1° 26′ gone in Meṣa. Therefore the true Sun = 0^r 1° 26′.

[चन्द्रस्फुटः]

‘रसगुणनवेन्दु’युक्ते ‘शशिगुणखगुणो’द्धृते घना द्युगणे ।
शेषे नवभिर्गुणिते गतयो‘ष्टजिनैः’ पदं शेषम् ॥ २ ॥

घनषोडशहृतशेषं प्रोज्झ्याऽधस्त्रिगुणितं चतुर्भक्तम् ।
भादि कला द्विगुणघनाः ‘शशिमुनिनवयमा’श्च राश्याद्याः ॥ ३ ॥

‘विषयधृतयो’ गतिघ्ना गति(का)ष्ठांशोनिताः कलाः प्रोक्ताः
‘वेदार्का’ः पदसंख्यागत्यर्धं धनमृणं परतः ॥ ४ ॥

True Moon

2. Add 1936 to the Days from Epoch, and divide the Sun by 3031. The quotient are called *ghanas.* Multiply the remainder by 9 and divide by 248. The quotient are called *gatis* and the remainder are called *padas.*

3. Divide the *ghanas* out by 16 and take remainder alone. Multiply this by 3, divide by 4 and take the result as *rāśi* etc. Subtract this from 12 *rāśi* and take the remainder. Add to this, minutes equal to twice the total *ghanas*. Add also 1^r 7° 29′. (The mean Moon at the end of the *ghanas* is got).

4. Multiply the *gatis* by 185, subtract a tenth of the *gatis* and add these also, taken as minutes. (The mean Moon at the end of the *gatis* is got.) If the number of *padas* is less than 124, they are called plus-*padas.* If 124 or more, 124 *padas* are taken and set apart as a half-*gati.* The remaining *padas* are called minus-*padas.* (The three technical terms here, half-*gati*, plus-*pada* and minus-*pada* are for use in verses 5 and 6 below.)

The reading here, *gatiṣaṣṭāṃśa* is wrong, it must be either *gatikāṣṭhāṃśa* or *gatyaṣṭāṃśa*. If, as we have said, two minutes are *added* per *ghana*, ‘added’, because addition is normally implied when

2a. A (= A1.2.) युक्त’; B (B1.2.3.) युक्तं
b. B. गुणो धृते
A. द्यता for धना
d. B. प्रदं
3a. A1. द्यनहृतं शेषं; A2. B2. द्यनषोडशहृतं शेषं
B1. हतं शेषं
b. A. प्रोज्जयाद्यस्त्रि; B.2. प्रोज्याद्यस्त्रि; C. प्रोह्याधस्त्रि
c. C. भादिफलं A1. द्विगुणद्यना; A2. धना;
B. कलद्विगुणधना (B2. ॰णा॰)
d. A. यमाश्र्व; D. om श्र्व C. हताश्र्च
4a. B1. गृनतिघ्रा षष्ठां॰; B2.3. गतिघ्रा षष्ठां
b. A1. गततिषष्टां॰; D. गतिषष्ठां॰. B1.2. शोन्निताः.
B2. प्रोक्ता
c. B. वेदार्कापाद॰. D. संख्या गत्यर्धं
c-d. B1.2. ॰ख्या भगत्यर्द्धं
d. C. पदतः

nothing is said, then the emendation *gatikāṣṭhāṃśa* is the proper one, which we have given. (TS also give this). If, on the other hand, we take it that the instruction is to subtract 2 minutes per *ghana*, taking the word *projjhya* in the previous instruction to be understood here also, then the emendation *gatyaṣṭāṃsa* will be the proper one. In this case we would also have to keep the letter *ṭa* of the original as it is, without changing it into *ṭha*. But the addition of 2 minutes per *ghana* alone would agree with the correct mean motion for the period of our author which is in cycles etc. 110-11-7-32-15 for 3031 days, the Vāsiṣṭha mean motion being 110-11-7-32. *NP* have emended the word as *ṣaṣṭhāṃsa* which would not give the correct result.

Example 2. Find the mean Moon for the end of the gati just before Days from Epoch, 3,06,131.

Adding 1936 to Days from Epoch, the days for computation got is, 1936 + 3,06,131 = 3,08,067. Dividing by 3031, the quotient 101 got are *ghanas*. The remainder is 1936. Multiplying 1936 by 9 and dividing by 248, the quotient 70 are *gatis*. The remainder, 64, are *padas*. These being less than 124, are plus-*padas*, to be used in the formula of verse 6.

Dividing out the *ghanas* by 16, the remainder is 5. This multiplied by 3 and divided by 4 gives *rāsis* etc., $3^r\ 22°\ 30'$. Subtracting this from 12 *rāśis*,

the remainder to be taken	= $8^r\ 7°\ 30'$
Add minutes equal to twice the *ghanas* = 101 × 2 minutes	= 0 3 22
Add the *kṣepa*	= 1 7 29
Add *gatis* × (185 − 1/10) minutes = 70 × 184 9/10 min.	= 7 5 43
The mean Moon at the end of the last *gati*	4 24 4

गत्यर्धे भगणार्धं देयं लिप्ताचतुष्कसंयुक्तम् |
शेषपदसमाश्चांशाः त(त्र) धनर्णात् फलं (वण्ड्यम्) || ५ ||
व्येकपदमिन्द्रियघ्नं कृतनवदश-संयुतं वियुक्तं च |
'मनुवेदयमे'भ्यः पदगुणे त्रिषष्ट्योद्धृते लिप्ताः || ६ ||

5. If a half-*gati* has been obtained, for the sake of that half-*gati*, add *rāśis*, etc. 6-0-4. Add also degrees equal in number to the plus-*padas* or minus-*padas*. Using the plus-*padas* or minus-*padas*, respectively, in the two following formulae, find the value, which is in minutes and add that also. (The true Moon is got).

6. Deduct one from the plus-*padas* or minus-*padas* and multiply by 5. If plus-*pada*, add the product to 1094, multiply this sum by the plus-*padas* and divide by 63. These are the minutes to be added. If minus-*pada*, subtract the product from 2414, multiply the remainder by the minus-*padas* and divide by 63. These are the minutes to be added.

5b. A. लित्पाश्चयुष्क
c. A1. समश्वांशाः; A2. सभाश्वांशाः
d. A1. तश्च; A2. B.C.D. तैश्च
A. धनर्णात्; B. धनर्णात्फिलं (B2 ०णा०)
A. दन्त्यम्; B. दत्य ।
6a. B1.3. ०न्द्रियघ्न
b. B3. दशं. B. द्वियुक्तं
d. A.B.1. त्रिषृट्योधृते; A. लिप्ता

The two formulae can be written down thus:
(i) If P is the number of plus-padas, $\{1094 + 5(P - 1)\}$ P/63.
(ii) If P' is the number of minus-padas, $\{2414 - 5(P' - 1)\}$ P'/63.

Example 3. Continue Ex.2 and compute the true Moon for the days given.

The mean Moon got in Ex. 2 to the end of the gati	=	4^r	24°	4′
The *padas* obtained are 64, plus-*padas* (P)				
Adding degrees equal to P = 64,	+	2	4	0
Using formula (i) intended for plus-*padas*, {1094 + 5 (64 − 1)} 64/63 = 1431 minutes	+	0	23	51
The true Moon		7	21	55

Example 4. The Days from Epoch are 1219. Find the True Moon.

1219 + 1936 = 3155 (= days for computation). Dividing by 3031, *ghana* got is 1, remainder 124. Multiplying 124 by 9 and dividing by 248, the *gatis* got are 4. The remainder 124 are *padas*. This is just one half-*gati* and no *pada* is left over.

		r	°	′
Ghana 1 × 3/4 = 0^r 22° 30′. Deducting from 12 *rāśis*	=	11	7	30
Adding minutes 1 × 2	+	0	0	2
Kṣepa	+	1	7	29
Gatis 4, × 184 9/10 = 740 (minutes)	+	0	12	20
For the half-*gati*, add	+	6	0	4
True Moon		6	27	25

Example 5. Find the true Moon for Days from Epoch, 1228.

1228 + 1936 = 3164 (= days for computation). Dividing by 3031, *ghanas* got 1, remainder 133. Multiplying by 9 and dividing by 248, the quotient 4 are the *gatis* got, and the remainder 205 are *padas* left over. A half-*gati* (= 124 *padas*) can be taken from this, and the remaining 81 are minus-*padas*.

		r	°	′
ghana 1 × $3/4^r$ = 0^r 22° 30′. Deducting from 12 *rāśis*		11	7	30
Adding 1 × 2 minutes	+	0	0	2
Adding *kṣepa*	+	1	7	29
Gatis, 4, × 184 9/10 = 740 (minutes)	+	0	12	20
For the half-*gati*	+	6	0	4
Degrees equal to P′ = 81′	+	2	21	0
Using formula (ii) (as the left over are minus-*padas* = P′), 2414 − 5 (81 − 1) 81/63 = 2589 mts.	+	1	13	9
True Moon		11	1	34

The following is the explanation of the processes: The true Moon at a given time *t* is: (i) the mean Moon at *t* plus (ii) the equation of the centre for *t*. (i) is given here in five parts. We shall call them *(a)*, *(b)*, *(c)*, *(d)*, *(e)* which are to be added up to get the total mean Moon.

(*a*) (Usually called the *Mūla-dhruva* or *Kṣepa*) is the mean Moon at a point of time 1936 days before the Epoch, when the Moon's apogee and the mean Moon exactly coincided according to this *Siddhānta*. This is given as *śaśi-muni-navayamāś ca rāśyādyāḥ*, i.e. $1^r\ 7°\ 29'$.

(*b*) is the mean motion during whole numbers of cycles of 3031 days from the point of time 1936 before Epoch, each cycle equal to 110 anomalistic revolutions of the Moon. This (b) is found by multiplying the mean motion per cycle (110 revolutions, 11 *rāsis*, 7 degrees, 32 minutes) by the number of cycles, called *ghanas*, obtained as quotient, by dividing the Days from Epoch plus 1936, by 3031. As full revolutions can be neglected, it is enough if we multiply the *ghanas* by 11 *rāśis* 7 degrees 32 minutes, which may be done as *ghanas* × 2′ + *ghanas* × $11^r\ 7°\ 30'$. *Ghanas* × 2 is given by *dviguṇaghanāḥ kalāḥ (yojyāḥ)*. Because 16 *ghanas* × $11^r\ 7°30'$ equals 15 full revolutions, it is enough if we divide out the *ghanas* by 16 and take the remainder alone for multiplication (for we shall be neglecting only full revolutions), which we are asked to do by *ghanaṣoḍaśahṛta-śeṣam*. As $11^r\ 7°\ 30'$ is 3/4 *rāśi* less than a full revolution, we can multiply the remaining *ghanas* by 3/4 *rāśi* and take this as subtractive, which we are instructed to do by *projjhyādhas triguṇitam caturbhaktam bhādi (rāśyādi.)* Thus *b* is disposed of.

(*c*) is the mean motion during the subsequent full anomalistic revolutions called *gatis*, which form the quotient got by dividing the remaining days by the anomalistic period, 248/9 days, (i.e. multiplying the days left over by 9 and dividing by 248). For each *gati* the mean motion is 1 revolution and 184 9/10 minutes (which can be obtained by dividing the motion per *ghana*, viz. 110 rev. $11^r\ 7°\ 32'$ by the number of *gatis* in a *ghana*, viz. 3031 × 9/248). Hence the rule to multiply the *gatis* by 185′ and deduct minutes equal to 1/10 of the *gatis*. This is given by *viṣayadhṛtayo gatighnā gatikāṣṭhāṃśonitāḥ kalāḥ yojyāḥ*.

(*d*) What are now left of the days are ninths of days called *padas* (and these obviously would be less than 248). The mean motion per *pada* is 1 degree $27\ \frac{209}{248}$ minutes, and so *padas* × $1°\ 27\ \frac{209'}{248}$ should be added to complete the mean motion till *t*. Of this, the *Siddhānta* asks us to add 1° per *pada* first, which is given by *śeṣapadasamāścāṃśāḥ (yojyāḥ)*. This forms *d*.

(*e*) The residue $27\ \frac{209}{248}$ minutes per *pada*, forming (*e*), is combined with the equation of the centre (ii) and given by the two formulae of II.6. If the *padas* contain a half-*gati* (i.e. 124 *padas*) the value of (*d*) + (*e*) + (ii) for the half-*gati* part is combined together and given as 180° 4′. This is got as follows. As the half-*gati* is equal to 124 *padas*, *d* = 124°. (*e*) + (ii) given by the first formula of II.6 is: $\{1094 + 5(124 - 1)\}\ 124/63 = 3364' = 56°\ 4'$; $124° + 56°\ 4' = 180°\ 4' = 6$ *rāsis* 4 minutes, which is given by *gatyardhe bhagaṇārdham deyam liptācatuṣkasaṃyuktam* and which instruction has so much puzzled TS. But, of course, this is incorrect and the defect lies in the equation of the centre-part of the formulae in II.6, which give zero-value for the equation of the centre not at 124 *padas*, but at 133 *padas*, as we shall show presently.

We shall first explain II.6 by showing how the formulae here combine the residual mean motion, viz. *padas* × 27 209/248 minutes (= *e*) with what is identifiable with the equation of the centre (= ii). The equation of the centre of the *Vāsiṣṭha* is peculiar. Usually in the *Siddhāntas* the equation of the centre varies as the sine of the anomaly, and therefore is zero at zero degree anomaly, going to a minimum at 90°, again rising to zero at 180°, then going to a maximum at 270°, and then falling to 0 to 360°, i.e. zero°. Thus it is negative in the first two quadrants and positive in the third and fourth quadrants and of the form, '$-a \sin \theta$, where 'a' is the maximum or minimum numerical

value, and θ is the anomaly. Note that this is the first term of the series for the equation of the centre in modern astronomy, with its sign reversed, and the reversing is necessary because the anomaly was reckoned by the ancients from the apogee, not perigee. But in the *Vāsiṣṭha* it is of the form $-(665 - 5P)\,P/63$ for the first two quadrants and $+(665 - 5P')\,P'/63$ for the last two. These are derivable from the equation for the Moon's daily true motion given in III.4, (as we shall show there), which assumes the increase or decrease of motion as uniform. Here we shall assume them and derive the two formulae of II.6.

As said before, (e) + (ii) is given by the formulae and (ii) is $-(665 - 5P)\,P/63$, for the first formula.
Therefore (e) + (ii) = $27\ 209/248\ P - (665 - 5P)\,P/63$
$= (63 \times 27\ 209/248 - 665 + 5P)\,P/63$
$= (1754 - 665 + 5P)\,P/63$
$= (1089 + 5P)\,P/63$
$= \{1094 + 5\,(P - 1)\}\,P/63$, which is the first formula.
For the second formula (ii) is $+(665 - 5P')\,P'/63$.
$\therefore$ (e) + (ii) = $27\ 209/248\ P' + (665 - 5P')\,P'/63$
$= (27\ 209/248\ P' \times 63 + 655 - 5P')\,P'/63 = (1754 + 665 - 5P')\,P'/63$
$= (2419 - 5P')\,P'/63 = \{2414 - 5\,(P' - 1)\}\,P'/63$ which is the second formula.

We have already shown how for the half-*gati* $6^r\,0°\,4'$ is got instead of the mean motion $6^r\,1°\,32\frac{1}{2}'$. This means that there is in this an equation of the centre equal to $-88\frac{1}{2}'$, combined with it. So, when the equation of the centre given by $+(665 - 5P')\,P'/63 = +88\frac{1}{2}$, then it is actually zero according to this *Siddhānta*. Solving this equation, we get $P' = 9$ or $P' = 124$. As P′ is minus-*pada*, which is the original *padas* got less 124, we get that the equation of the centre actually becomes zero at original *padas*, P= 133, and P = 248. As P = 248, is the end of the *gati*, this is what we expect, as the anomaly has again become zero.

Also, by computation or examination we can get from the equation of the cyclic part of the formula for the first half-*gati*, $-(665 - 5P)\,P/63$, the numerically greatest value of the negative equation of the centre, which is $-351'$, for $P = 66\frac{1}{2}$. In the same way, from that the formula for the second half-*gati*, $+(665 - 5P')\,P'/63$ we can get the maximum $+351'$, for $P' = 66\frac{1}{2}$; but as there is a residue of $-88\frac{1}{2}'$ in the second half-*gati*, $351' - 88\frac{1}{2}' = 262\frac{1}{2}'$ is the actual maximum. The numerical mean is 307′ which, we see, is very nearly equal to that of the other Hindu *Siddhāntas*.

It is not that VM does not know that zero equation of the centre must occur at P = 124, and not at 133, for in his own *Romaka* and *Saura* it is so. Nor is it difficult for VM, a master in the science, to give the two formulae so as to have the equation of the centre zero at P = 124, (so that for a half-*gati* we get the correct $6^r\,1°\,32\frac{1}{2}'$), retaining, at the same time, the equation of the centre desired by him. If he had given the two formulae in the form $(1134 + 5P)\,P/63$, and $(2374 - 5P')\,P'/63$, he could have secured this. But adherence to the *Siddhānta* has prevented him from doing this. So closely does he follow the original that he does not even give the two formulae in the more simplified forms, $(1089 - 5P)\,P/63$, and $(2419 - 5P')\,P'/63$.

The following things are to be noted in connection with this *Siddhānta*. Of both the Sun and the Moon, the mean motion and the equation of the centre is mixed in a peculiar manner and thereby the true motion is given. We shall see that it is the same in the case of the *Pauliśa* also.

The period of 3031 days called *ghana* here is the same as what is called *kālānala* in the *Vākyakaraṇa*, which gives for this period, the mean motion, $11^r\,7°\,31'$, neglecting full revolutions. The number 248 given here is there mentioned as *devara*.

We can see that the remark in I.4 about the *tithi* of the *Vāsiṣṭha* being very incorrect is appropriate, but it can be shown that it is not due to the error in the Moon, but in the Sun, whose sidereal year is taken as 365-15-0 days. The Moon's motion for 3031 days is in cycles etc. 110-11-7-32 = 110 5063/5400 cycles. In one day the motion is 110 5063/5400÷3031 = 5,99,063/ (5400 × 3031) cycle. In one day the Sun's motion is 1/365¼ = 4/1461 cycle. The relative motion, i.e. their separation per day is 5,99,063/(5400 × 3031) − 4/1461 cycle. The time taken for a separation of one cycle, i.e. the synodic month, is in days, 1/{59,90,63/(5400 × 3031) − 4/1461} = 1461 × 3031 × 5400 ÷ (1461 × 5,99,063 − 4 × 5400 × 3031) = 7,97,09,23,800 ÷ 26,99,20,481 = 29 - 31 - 50 - 17 - 38. But the correct synodic month computed for the time near that of our author is 29 - 31 - 50 - 7 - 47. Therefore in successive synodic months the *tithi* comes later by days etc. 0-0-0-9-51, according to *Vāsiṣṭha*. In about 29½ years this will accumulate to one *nāḍikā*. This is bad indeed, and merits VM's remark in I.4 *taditarau dūravibhraṣṭau* (i.e., 'The *tithis* of the other two have slipped far away from the real'.)

Now, we have seen that according to this *Siddhānta* the mean Moon moves revs. 110-11-7-32-0, while the real motion for the period is revs. 110-11-7-32-15. Therefore in 3031 days the *Vāsiṣṭha nakṣatra* is delayed by a little more than one *vināḍi*. So a delay of one *nāḍi* is caused in 440 years only. So the delay of one *nāḍi* in the *tithi* per 29½ years mentioned above, must be due almost wholly to the error in the Sun, the result of giving the time per cycle as 365-15-0 days.

Again, in every 3031 days, the *Vāsiṣṭha* Moon lags behind the correct one by 15″. A lagging behind by one degree will take place in 3031 × 60 × 60 ÷ 15 days, i.e. in about 2000 years, a very long period indeed. Bearing this in mind, we shall try to answer the question already raised, viz. whether the *Vāsiṣṭha* Sun and Moon are given for sunrise at Ujjain or sunset at Yavanapura; and, incidentally, we shall show that the *kṣepa*, 1ʳ 7° 29′ given by *śaśi-muninavayamāśca rāśyādyāḥ* and obliterated by TS by their drastic emendation as *yama-hṛtāś ca* is necessary in II.3.

The following is the mean Moon for Epoch (viz. Śaka 427 elapsed, i.e. in A.D. 505), sunset, at Yavanapura, beginning Monday, Caitra Śukla being about to begin.

i.	Computed for the period according to modern astronomy, assuming the *ayanāṃśa* to be practically 0 for the time		354° 48′
ii.	According to *Saura*		355° 6′
iii.	According to *Siddhānta Śiromaṇi*		355° 41′
iv.	According to *Romaka*		356° 12′
v.	According to *Vāsiṣṭha*, assuming that the mean Moon is given for Ujjain sunrise		355° 6′
	-do-	-do- for sunset at Yavanapura	346° 54′
	-do-	Ujjain sunrise, without *Kṣepa*	317° 37′
	-do-	sunset at Yavanapura without *Kṣepa*	309° 25′

(For use by anyone interested in making the calculations himself, the Kalidina etc. of Epoch is 13,17,122-37-20. Also, the Epoch is 5,09,432-22-40 days before mean sunrise at Ujjain of the first January 1900).

An examination of the table will show that the *Vāsiṣṭha* Moon agrees with that of every other fairly well, taking it as being given for Ujjain sunrise, and taking that the *kṣepa* is given. If, on the other hand, it is assumed that it is given for sunset at Yavanapura, there is a difference of about 8°, which can happen only in 1600 years, which is very very unlikely; for this to happen the *Vāsiṣṭha* should

have been written 1600 years earlier. If there is not the *kṣepa,* the difference is 37°, an impossible thing, not to speak of the assumption that it is for Yavanapura sunset and there is no *kṣepa*, both together which will make the difference 45° and worse. Hence the *Vāsiṣṭha* epoch is definitely at sunrise at Ujjain and not at sunset at Yavanapura (Alexandria).

We have shown the *kṣepa* necessary. But TS have emended *kalāḥ dviguṇaghanāḥ, śaśi-muni-navayamāś ca rāśyādyāḥ* (verse 3) into *phalaṁ dviguṇaghanāḥ śaśi-muni-yama-hṛtāś ca rāśyādyāḥ* and spoiled the already correct reading and introduced two extra syllables in the last foot, which spoils the *āryā* metre too. (It must be noted that already there are 16 *mātrās* in the last foot, i.e. one *mātrā* extra, which can be explained away or corrected by reading *rāśyādyāh as rāśyādi.)*

One another point: TS have expressed their inability either to interpret II.6 or to explain why 6^r 0° 4′ is to be added for a half-*gati* (vide Com, page 9). But still thinking II.6 gives the pure equation of the centre, the commentary goes on: *arthāt vedārkālpa-padeṣu ṛṇam, adhikeṣu dhanam iti buddhimadbhiḥ svayam eva ūhyam,* i.e. "It goes without saying that when the *padas* are less than 124, the result is subtractive, and when more it is additive", which is wrong for we have seen that the result of both the formulae are additive. Moreover, the failure, both by TS and NP, to realise that the expression '*rāśyādyāḥ*' specifically instructs that the digits in *śaśimuninavayama* are to be taken as 'beginning from *rāśi*', i.e. as 1^r 7° 29′ and not as a whole number 2971 (TS) or as "2^r 9;7, 1^{0}" (NP) have led to incorrect interpretations by them; also, the Notes of NP (vol. II, pp. 16-19) and the deductions made (p.19) have to be revised in the light of all that has been stated above.

[नक्षत्र-तिथी]

श(श्यर्ध)दलं त्रिकृतिघ्नमृक्षमंश(स्थि)ता मुहूर्ताः स्युः ।
व्यर्केन्दुदलं विषयाऽऽहतं तिथिस्तद्वदेवोक्तः ॥ ७ ॥

Nakṣatra and Tithi

7. Divide the True Moon by 4 and multiply by 9. What we get in the *rāśi* column is the *nakṣatra.* What is got in the degree column are the *muhūrtas.* Deduct the true Sun from the true Moon, divide the result by 2 and multiply by 5. *Tithis* are got in the *rāśi* column and thirtieths of *tithis* in the degree column.

As the 27 *nakṣatra*-segments are divided into the 12 *rāśi* - segments, there are 2¼ = 9/4 *nakṣatras* per *rāśi*. Hence the instruction to divide the *rāśis* by 4 and multiply by 9 to get the *nakṣatras.* As degrees are thirtieths of *rāśis*, the resulting numbers in the degree column are thirtieths of *nakṣatras,* called *muhūrtas* by this *Siddhānta.* It must be noted that the word *muhūrta* originally meant the 30th part of a *nakṣatra,* but later came to be applied to the 30th part of a day as well, because both are practically the same in duration.

The interval of longitude between the Sun and the Moon is the *tithi,* 12° forming one *tithi*, i.e. there are 2½ = 5/2 *tithis* per *rāśi*. Hence the instruction to divide the *rāśis* by 2 and multiply by 5 to get the *tithis.*

7a. A. शशादलं; B. शशस्वदमन्त्रि
b. A. मंशस्छिता; B. ०मक्ष (B3. मक्षु) -मंशास्थिता
d. A. तिथिस्तंद्व०

Example 6. The true Sun is 10^r 18°, and the true Moon is 5^r 22°. Find the nakṣatra and the tithi.

Nakṣatra: The Moon is 5^r 22°. Dividing by 4, (5^r 22°)/4 = 1^r 13°. Multiplying by 9, 9x 1^r 13° = 12 – 27, i.e. twelve *nakṣatras* have gone and in the 13th, (Hasta), 27 *muhūrtas* have gone.

Tithi: Moon – Sun = 5^r22° – 10^r18° = 7^r4°. Dividing by 2, (7^r4°)/2 = 3^r17°. Multiplying by 5, 3^r 17° × 5 = 17 – 25. Seventeen *tithis* are gone and in the eighteenth (Bahula Tṛtīyā) 25/30 parts have gone.

[अहर्मानम्]

मकरादौ 'गुण'युक्तो मोषादौ 'तिथि'युतो र(वि)र्दिवसः ।
कर्कटकादिषु सत्सु 'त्रयस्त्रिकाः' शर्वरीमानम् || ८ ||

Day-time

8. When the Sun is in the 3 *rāśis,* Makara etc., the Sun measured in *rāśis* plus three is the duration of day-time in *muhūrtas.* When it is in the 3 *rāśis,* Meṣa etc., the Sun plus fifteen is the duration of day-time. When in the 6 *rāśis,* Karkaṭaka etc., the Sun plus nine is the duration of the night-time. (To get the duration of the day-time, this should be subtracted from 30).

Though no measure of time is mentioned here, we can infer that it is the *muhūrta* (2 *nāḍis)* because by adding the shortest day, 12, and the longest, 18, we get 30 which must be equal to the whole day, i.e. 60 *nāḍikās.*

Thus, for the Sun at the beginning of each *rāśi,* Meṣa etc., the day-time in *muhūrtas* is 15, 16, 17, 18, 17, 16, 15, 14, 13, 12, 13, 14. The longest day is 18 *muhūrtas* when the Sun is at the first point of Karkaṭaka (Cancer) at Summer solstice and the shortest 12 *muhūrtas* when at the first point of Makara (Capricorn) at Winter solstice. The day and night are equal at the first points of Meṣa (Aries) and Tūla (Libra), i.e. at the equinoxes. The daily increase or decrease in day-light is 4 *vināḍis* per day. In essence, the same formula for day-light is found in the *Vedāṅga Jyotiṣa* and the *Paitāmaha Siddhānta* (PS, XII.5),with this difference that here the true Sun is used, but there, because they have no true Sun but only the mean Sun, the day which is proportionate to the mean Sun, is used.

Evidently not understanding what is given here, TS have made a drastic change in the text, writing *bhūsvarga-tithimito* for *meṣādau tithiyuto,* intending to make this agree with the next verse giving the noon-day shadow. But, even within that verse, there is contradiction and this need not have been attempted, at such cost. To crown all their interpretation with their emendation is full of contradiction within itself, which has been set out in detail by me in a paper entitled 'Vāsiṣtha Sun and Moon' in the *Journal of Oriental Research,* 25 (1955-56) 19 –41.

The uniform increase and decrease in day-time given here is wrong, of course, and it varies with the position of the Sun, being greatest at the equinoxes and falling to zero at the solstices. The maximum or minimum day-time itself varies with the latitude of the place (depending on *tan.*

8b. A. मेखादौ. C. भूस्वर्गतिथिमितो रवेर्दिवसः
A.B.C. रवेः. A2. दिक्रमृ ।

c. B2. सत्सुः; C.D. षट्सु
d. B. मानाम्

latitude), what is given here being for some place having a North latitude of 35° 45′. (This matter is dealt with in the text in III.10 and IV.26).

The rules for day-time is explained thus: From the beginning of Makara to the end of Mīna the Sun in *rāśis* increases from 9 to 12. The day-time also increases following it, from 12 *muhūrtas* at winter solstice to 15 at Equinox. As (9 to 12) + 3 = (12 to 15), the instruction to add 3 for the Sun in this quadrant follows. In the same way, from the beginning of Meṣa to the end of Mithuna, the Sun in *rāśis* increases from 0 to 3. The day-time increases from 15 at Equinox to 18 at summer solstice. (0 to 3) + 15 = (15 to 18), and this explains the addition of 15. As there is the maximum day of 18 *muhūrtas* at summer solstice, there is the minimum night there, of 12 *muhūrtas*. This increases to maximum night, 18 *muhūrtas* for Sun at the beginning of Makara, 6 months after. As a result, as the Sun's *rāśi* increases from 3 to 9, the night increases from 12 to 18. (3 to 9) + 9 = (12 to 18) and this explains the addition of 9 (three times three).

Example 7. Give the day-time for the Sun at the beginning of: (i) *Ṛṣabha,* (ii) *Kumbha and* (iii) *Kanyā.*

(i) The Sun is in the quadrant 0 to 3 *rāśis*. The beginning of Ṛṣabha is one *rāśi*. Therefore 1 + 15 = 16, *muhūrtas,* is the day-time.

(ii) The Sun at the beginning of Kumbha is 10 *rāśis*. This is in the quadrant 9 to 12. Therefore 10 + 3 = 13, *muhūrtas,* is the day-time.

(iii) The Sun at the beginning of Kanyā is 5 *rāśis* and is in the 6 *rāśis* 3 to 9. Therefore 5 + 9 = 14, *muhūrtas*, is the night-time. Deducting from 30, 30 − 14 = 16, *muhūrtas,* is the day-time.

[शङ्कुच्छाया]

कर्कटकादिषु भुक्तं द्विगुणं माध्यन्दिनी भवेच्छाया |
मकरादिषु चाप्येवं, (किंत्वस्मिन्) मण्डलाच्छोध्यम् || ९ ||

मध्याह्नच्छायार्धं सत्रिभमर्कोऽयने भवेद्याम्ये |
उदगयने संशोध्यं पञ्चदशभ्यो रविर्भवति || १० ||

Gnomonic Shadow

9. When the Sun is in the six *rāśis* beginning with Karkaṭaka, the number of *rāśis* traversed from the beginning of Karkaṭaka, multiplied by 2, is the mid-day shadow (of the twelve-digit gnomon) in digits. When the Sun is in the six *rāśis* beginning with Makara, find the distance in *rāśis* traversed by the Sun from the beginning of Makara, and multiply by 2. Subtract this from 12, to find the mid-day shadow.

10. When the Sun is in its southward-course, (i.e., in the six *rāśis* from Karkaṭaka), half the mid-day shadow *plus* three is the longitude of the Sun in *rāśis*. When in the northward course in the six *rāśis* from Makara, half the noon-shadow subtracted from fifteen is the Sun in *rāśis*.

9a. A1. कर्कटादिषु; B2 °दिवु. B. भक्तं
b. A.B1. मध्यंदिनी. A. भवेछाया
c. A1. वाप्येव; A2. वाप्येवं
d. A.B.C.D. किं चास्मिन्. A. मंण्डलाछोध्याम्; B. मडलात्सोध्या
10a. A1. °ह्नछायार्द्धं
d. B. पञ्चदशेभ्यो

Example 8. (a) On a certain day the Sun's longitude is 5 rāśis. (b) On another day it is rāśis 11-15. In both cases find the mid-day shadow.

(a) The Sun is 5 *rāśis* and is within the six *rāśis* from Karkaṭaka, being 2 *rāśis* from the beginning of the first point of Karkaṭaka (i.e. 3 *rāśis*). So, $2 \times 2 = 4$ digits is the shadow.

(b) The Sun's longitude is *rāśis* 11-15. This is within the six *rāśis* from the first point of Makara (9 *rāśis*), the Sun's position being $11^r\ 15° - 9^r\ 0° = 2^r\ 15° = 2\frac{1}{2}$ *rāśis* from that point. $12 - (2\frac{1}{2} \times 2) = 7$ digits is the noon-shadow,

Example 9. (a) The Sun is in its southward course and the shadow is 4 digits. Find the longitude of the Sun. (b) The Sun is in its northward course and the noon-shadow is 7 digits. Find the Sun.

(a) Half the shadow $= 4/2 = 2$. As the course is southward add 3 *rāśis*; the Sun's longitude is 5 *rāśis*.

(b) Half the shadow $= 7/2 = 3\frac{1}{2}$. As the Sun's course is northward, deduct from 15. $15 - 3\frac{1}{2} = 11\frac{1}{2}$ *rāśis*. This is the longitude of the Sun.

From the two sets of examples it can be seen that the two formulae are the inverse of each other.

The formulae are explained thus: This *Siddhānta* assumes that the noon-shadow is zero when, at the end of its northward course, it reaches the first point of Cancer. Then as it moves southward, the shadow increases to 12 digits at the end of the course, i.e. after 6 months, when the Sun reaches the first point of Capricorn. Assuming the increase to be uniform, there is an increase of 2 digits per *rāśi*. As the shadow is zero for the first point of Cancer, the longitude in *rāśis* measured from this point, multiplied by 2 gives the shadow. Thus, if c is the Sun in *rāśis* measured from the first point of Cancer and s is the shadow in digits, $s = 2c$ for the 6 months till the Sun reaches Capricorn, where the shadow is $6 \times 2 = 12$ digits. Then the shadow decreases at the same rate to zero at the first point of Cancer, in the course of 6 months. Therefore if c is the Sun measured from the first point of Capricorn, when the shadow is 12, and s the shadow, then $s = 12 - 2c$.

Now for the longitude of the Sun from the noon-shadow. We have seen that for the six *rāśis* from Cancer, $s = 2c$. Therefore $c = s/2$. But c is counted from the first point of Cancer, i.e. 3 *rāśis*. Therefore the Sun's longitude in *rāśis* is $3 + c = 3 + s/2$, which is the same as the instruction to divide the shadow by 2 and add three *rāśis*. For the six *rāśis* from Capricorn, we have seen that $s = 12 - 2c$. Therefore $c = (12 - s)/2$. But c is counted from the first point of Capricorn. i.e. 9 *rāśis*. Therefore the Sun $= 9 + c = 9 + (12 - s)/2 = 15 - s/2$, which is the instruction given.

It must be noted here that both the formulae are very rough. At summer solstice, when the Sun is at the first point of Cancer, its north declination is maximum and given by Hindu astronomy as 24°. At that time, the mid-day Sun is at the zenith at places on 24° north latitude (like the region of Ujjain) and so it is only in this region that the shadow is zero at this time. When the Sun reaches its southernmost point at winter solstice, i.e. the first point of Capricorn, its south declination is 24°. Therefore the zenith distance of the noon-Sun as seen from latitude 24° North at that time must be 48° towards the South, and the shadow at that time must be greater than 13 digits and not 12. (All this will be shown in Chapter IV). If the shadow is to be 12 digits, the Sun's zenith-distance must be 45° and the region where the Sun is seen at this zenith-distance is 21° North latitude. Thus there is contradiction even here. In verse 8, we showed that the rule is intended for a region having about 36° North latitude, neither 24° nor 21°. Thus, so far as these things are concerned, the *Siddhānta* seems to be a hotch-potch.

[छायातो लग्नं लग्नतः छाया च]

द्वादशभिः सच्छायैर्मध्याह्नोनैर्भजे'द्रसहुताशम्' |
अपराह्णे चक्रार्धाद्विशोध्य सार्कं भवति लग्नम् || ११ ||

Lagna from shadow and vice versa

11. Add 12 to the shadow (of the twelve-digit-gnomon, measured in digits) at any time of the day, and deduct from it the mid-day shadow for the day. Divide 36 by this and take the result. This result taken as *rāśis,* plus the Sun in *rāśis* is the *lagna* at the moment, if it is forenoon. If afternoon, deduct this from the Sun plus six *rāśis* and the *lagna* is got.

The formulae (a) for the forenoon and (b) afternoon respectively can be expressed thus: (a) *Lagna* = Sun + 36/(12 + shadow − noon shadow). (b) *Lagna* = Sun + 6 − 36/(12 + shadow − noon shadow).

What is called *lagna* is the Orient Ecliptic Point, i.e. the point of the ecliptic rising on the eastern horizon.

Example 10. (a) On a certain day, the Sun is 9 rāśis and the mid-day shadow 12. At a time in the morning the gnomonic shadow is 36. Find the lagna for the moment. (b) On a certain day, the longitude of the Sun is 6 rāśis and the noon-shadow 6 digits. At a time in the evening the gnomonic shadow is 24 digits, find the lagna for that moment.

(a) From formula (a), *Lagna* = 9 + 36/(12 + 36 − 12) = 9 + 1 = 10, *rāśis*. Hence the first point of Kumbha is rising in the east.

(b) From formula (b), *Lagna* $= 6 + 6 - 36/(12 + 24 - 6) = 12 - 1\frac{6}{30} = 10\frac{24}{30}$ *rāśis*. Hence the 25th degree of Kumbha is rising in the east.

These rules are rough and there is no question of strictly proving them. But we can explain them thus. From sunrise to noon, as the altitude of the Sun increases, the *lagna* goes on increasing and the shadow decreasing, till it is shortest at noon. Therefore the increase in *lagna* can be roughly expressed as, a/(shadow + b), where a and b are constants to be determined. Now, if the place is supposed to be situated on the equator, and the ecliptic on which the Sun moves is supposed to coincide with the celestial equator, then at noon the shadow will be zero. At that time the increase in *lagna* (after sunrise) would be 3 *rāśis,* as the Sun has reached an altitude of 90°. Therefore $3 = a/(0 + b)$. Again, seven and a half *nāḍis* after sunrise, the Sun would have risen to an altitude of 45°. So the increase in *lagna* now is 1½ *rāśis* and the shadow is 12 tan 45° = 12 digits. Therefore, $1\frac{1}{2} = a/(12 + b)$. Solving these two equations for a and b we get $a = 36$, $b = 12$. Therefore the increase in *lagna* is 36/(shadow + 12), of course, on the given two assumptions. But the place may not be on the equator and the ecliptic does not coincide with the celestial equator and the Sun moving on it has a varying declination, with the result that generally the noon-shadow is not zero. According to the length of the noon-shadow at other times also there will be an increase in the shadow over what

11a. A1.द्वाशभिः; A2.द्वादभिः. A.सछायै A2.द्रसंजताशं
b. B.मध्याह्नानै. B.हतांशाः. A1.॰द्रसजताशं; c. A.B.चन्द्रार्द्धाद्

it would otherwise be, for which the rule has been formulated. As the deduction of the noon-shadow for the day of observation from the shadow would, to some extent, remove this extra length of shadow and bring about an approximation to the ideal condition, the noon-shadow is asked to be deducted from the shadow in the formula. Therefore the increase in *lagna* is given by 36/(shadow − noon shadow + 12). As at sunrise the Sun is the *lagna*, adding the increase to the Sun we get the *lagna*, i.e. *lagna* = Sun + 36/(12 + shadow − noon-shadow). This is for the forenoon.

In the afternoon, what happens in the forenoon with reference to the shadow is reversed, and therefore the rule gives the part of the *lagna* to increase from the time of observing the shadow to sunset. So, it is less than the *lagna* at sunset by what is got from the formula. But the *lagna* at sunset is the Sun plus six *rāśis*. Therefore the formula for the afternoon becomes: Sun + 6 − 36/(12 + shadow − noon-shadow). Again let it be remembered that the rules are rough.

व्यर्के लग्ने लिप्ताः प्राक्पश्चाच्छोधितास्तु चक्रार्धात् ।
कार्यश्छेदः 'शून्याम्बराष्टलवणोदषट्कानाम्' ॥ १२ ॥

लब्धं द्वादशहीनं मध्याह्नच्छायया समायुक्तम् ।
सा विज्ञेया छाया वासिष्ठसमाससिद्धान्ते ॥१३ ॥

12-13. Deduct the Sun from the *lagna* and convert the remainder into minutes of arc, if forenoon. If afternoon, deduct the minutes from a half circle, (i.e. from 10,800 minutes), and take these as minutes. Divide 64,800 by the minutes got. Add the result to the noon-shadow of date and deduct 12 from this. This is the shadow at the time of the given *lagna*. This is according to the succinct *Vāsiṣṭha Siddhānta*.

The formula (a) for the forenoon, and (b) for the afternoon, respectively, are: (a) shadow = {64,800 ÷ (*lagna* − Sun, in minutes) + noon-shadow − 12}. (b) shadow = 64,800 ÷ {10,800 − (lagna − Sun, in minutes)} + noon-shadow − 12.

Example 11. (a) On a certain day at a time in the forenoon, the Sun is 9 rāśis and the lagna 10 rāśis and the noon-shadow of date is 12 digits. Find the shadow for the time. (b) On another day, for a time in the afternoon, the sun is 6 rāśis and the lagna 10 rāśis 25 degrees and the noon shadow of date is 6 digits. Find the shadow.

a] Using formula (a), shadow = 64,800 ÷ {(10 − 9) × 1800} − 12 + 12 = 36 digits.

b] Using formula (b), shadow = 64,800 ÷ {10,800 − (10 5/6 − 6) × 1800} − 12 + 6 = 64,800 ÷ (10,800 − 8640) − 12 + 6 = 64,800 ÷ 2160 − 12 + 6 = 30 − 12 + 6 = 24 digits.

These formulae (a) and (b) can be derived from the previous formulae (a) and (b) of verse 11, for these are only the inverse of the previous operations.

12a. B3. लिप्ता
b. A. प्राक्पश्चा A. छोधितास्तु; B. छोधितासु
B1. चक्राद्धतिः; B3. चक्रार्धात् । द्धतिः
c. A.B. कायछेदः (B3. कायः छेदः)

13. A1. लध्वं; A2. लध्व. B3. हिनं
b. A.B. ०ह्नछायया. B. समायुक्ता
d. A2. वासिष्ट; B1.2. वाशिष्ट; B3. वाशिष्ठ

The previous (a), is: *lagna* = Sun + 36/(12 + shadow − noon-shadow). Therefore, *lagna* − Sun = 36/(12 + shadow − noon-shadow). Therefore 36/(*lagna* − Sun) = 12 + shadow − noon-shadow. Therefore, shadow = 36/(*lagna* − Sun) + noon-shadow − 12, where it is to be noted that (*lagna* − Sun) is in *rāśis*. If it is to be expressed in minutes, we have, shadow = 36/(*lagna* − Sun) × 1800 ÷ 1800 + noon-shadow − 12 = 36 × 1800/(*lagna* − Sun) in minutes + noon-shadow − 12 = 64800/(*lagna* − Sun) in minutes + noon − shadow − 12, which is (a) here.

The previous (b) is: *lagna* = Sun + 6 − 36/(shadow + 12 − noon-shadow). Therefore 36/(shadow + 12 − noon-shadow)= Sun + 6 − lagna = 6 − (lagna − Sun). Therefore 36/{6 − (lagna − Sun)} = shadow + 12 − noon-shadow. Therefore shadow = 36/{6 − (lagna − Sun)} + noon-shadow − 12, where (lagna − Sun) is in *rāśis*. If it is to be expressed in minutes, we have, shadow = 36/6 − { 6 − (*lagna* − Sun) × 1800 ÷ 1800} + noon-shadow − 12 = 36 × 1800/{6 × 1800 − (*lagna* − Sun) in minutes} + noon-shadow − 12 = 64,800/{10,800 − (*lagna* − Sun) in minutes} + noon-shadow − 12, which is (b) here.

The concluding words, *Vāsiṣṭha-samāsa-siddhānte,* though forming a part of the sentence giving the rules of verses 12-13, may be detached from it and taken to refer to the whole chapter II and mean 'All this is given as in the succinct *Vāsiṣṭha Siddhānta'.*

The word, *nakṣatrādicchedaḥ* is found at the conclusion in the manuscripts. Perhaps it is, *nakṣatrādhicchedaḥ,* meaning 'Naksatra section' and the title is appropriate because this is the chief thing given here and other things depend on it.

Thus in this chapter the true Sun and Moon are given according to the *Vāsiṣṭha* and also other matters depending on them like the *nakṣatra,* the *tithi*, day-time shadow and *lagna*. (The star planets i.e. the regular planets, of this *Siddhānta* will be given in XVIII.)

TS have professedly not understood verses 1, 5 and 6 and gone wrong in verses 3 (and 8), which means they have practically not understood the *Siddhānta* at all. Thibaut even thinks that verse 1 may be dealing with the Moon. But this professed ignorance did not prevent him from making the unwarranted remark in the Introduction (vide p. XXXVIII)..... "the methods are so crude and so completely omit to distinguish between mean and true astronomical quantities, that the Vasistha Siddhanta can hardly be included within Scientific Hindu Astronomy."

[इति पञ्चसिद्धान्तिकायां वराहमिहिरविरचितायां
वासिष्ठसिद्धान्ते ग्रहादिगणितं नाम द्वितीयोऽध्यायः ||]

A.B. have as Colophon, नक्षत्रादि छेदः; C.D. नक्षत्रादिच्छेदः |

Thus ends Chapter Two entitled 'Vāsiṣṭha-Siddhānta: Planetary Computations etc.' in the Pañcasiddhāntikā composed by Varāhamihira

Chapter Three

PAULIŚA-SIDDHĀNTA — PLANTERY COMPUTATIONS ETC.

३. तृतीयोऽध्यायः
पौलिशसिद्धान्तः — ग्रहादिगणितम्

Introductory

This chapter is a compendium of the part of the *Pauliśa Siddhānta* dealing with the Sun, Moon and Rāhu. It has already been mentioned that the original *Pauliśa* is now lost, perhaps for ever. This and the *Saura* are the only *Siddhāntas* dealt with by the author in full, the others being scrappy. For some reason not known to us, at present the *Pauliśa* is mixed up with the *Vāsiṣtha,* for, the mean Moon, together with its peculiar technical terms *pada, gati* and *ghana* are used here, without mentioning how they are got. The formula for the Moon's daily true motion, which patently belongs to *Vāsiṣtha* has strayed into this chapter, another evidence of their being mixed up. In this chapter the Sun, the Moon and Rāhu, the methods of computing the daily *nakṣatra, tithi* and *karaṇa,* the two *yogas vyatīpāta* and *vaidhṛti,* the day-light in any given place in India, and certain holy days necessary for religious observations are dealt with.

[स्फुटरविः]

'खार्क'घ्नेऽ'ग्निहुताशन'मपास्य 'रूपाग्निवसुहुताशकृतैः' |
हृत्वा क्रमाद् दिनेशो मध्यः केन्द्रं सविंशांशम् || १ ||
'एकादशा''ऽष्टषट्कं' 'रूपोना सप्ततिः' 'ख'युक्ता च |
'नवषट्क''मु(त्कृ)ति'श्च क्षयः कलाः केन्द्रराशिसमा : || २ ||
'दश' 'षट्काष्टक' 'सप्तति' 'सप्ततिरेकाधिका' च 'नवषट्कम्' |
'पञ्चकृति'श्चोपचयो मध्यमसूर्यः स्फुटो भवति || ३ ||

True Sun

1. Multiply the days from Epoch by 120, deduct 33 and divide by 43,831. The mean Sun in revolutions, *rāśis* etc. is obtained. Add 20° to this mean Sun. What is called *kendram* is got.

2-3. For the first six *rāśis* of *kendra* there are the following six quantities: 11, 48, 69, 70, 54 and 26, all deductive and in minutes. For the next six *rāśis* are the following: 10, 48, 70, 71, 54 and 25, all additive and in minutes. (If these are taken one after another according to *rāśis* of the *kendra* gone and) applied to the mean Sun, it becomes true Sun.

In short, these twelve quantities are intervals of the equation of the centre for every *rāśi* of the *kendra*, the word being used in a peculiar sense here, and not the usual one of mean anomaly. The faulty readings, *munyakṛti, muptakṛta* is corrected as *mutkṛti,* meaning 26, and thereby the excess of one syllable in the foot also gets corrected. TS and NP have emended it as *makṣakṛti,* meaning 25, which, by its form, seems to be less likely to be the original, and which keeps the defect of the excess of one syllable.

Example 1. (a) Find the true Sun for days from Epoch 690. (b) Compute the true Sun at Epoch.

(a) Multiplying the days 690 by 120 and deducting 33, we have, $690 \times 120 - 33 = 82{,}767$. Dividing by 43,831, the revolution got is 1 and remainder 38,936. Multiplying this by 12 and dividing by 43,831, the *rāśis* got is 10. The remainder is 28 9/22, which multiplied by 30 and divided by the same divisor, gives degrees 19. The remainder 34,871 multiplied by 60 and divided by the same divisor gives 48 minutes. Thus the mean Sun is, omitting revolutions, *rā.* 10-19-48. *Kendra* = Mean Sun + 20° = *rā.* 10-19-48 + 20° = *rā.* 11-9-48. For 11 full *rāśis* of *kendra* and 9° 48 ′ of the 12th, the minutes to be applied are, $-11, -48, -69, -70, -54, -26, +10, +48, +70, +71, +54, +25 \times 9°48'/30°$, which added together is -17. Applying this to the mean Sun, the true Sun is $10^r\,19°\,48' - 17' = 10^r\,19°\,31'$.

(b) At Epoch the days are zero. Therefore $0 \times 120 - 33' = -33$. Mean Sun $= -33/43{,}831$ revolutions $= -33 \times 12 \times 30 \times 60/43{,}831$ minutes $= -16' = 11^r\,29°\,44'$, (since cycles of 12 *rāśis* can be added or omitted). *Kendram* $= 11^r\,29°\,44' + 20° = 0^r\,19°\,44'$. As no full *rāśi* or *kendram* is gone and there are 19° 44′ in the first *rāśi,* the minutes to be applied are: $-11' \times 19°44'/30° = -7'$. The true Sun $= 11^r\,29°\,44' - 7' = 11^r\,29°\,37'$.

It is to be noted that the word *kendram* here is not used in its usual sense in later astronomical works, as the mean anomaly (counted from the Higher Apsis) which is obtained by deducting the longitude of the higher apsis from the mean planet. In fact, the use of the expression in modern western astronomy itself is different in the sense that the anomaly is obtained by subtracting the lower apsis or perigee from the mean planet. The *Sūrya Siddhānta* instructs that the *kendram* is to be obtained by deducting the mean planet from the higher apsis which is equal to the *kendram* given by others, subtracted from 12 *rāśis.* Thus the common characteristic of these different *kendras* is that it is used as the *argument* for the equation of the centre and in this sense its use is appropriate here also. So we can take it that the mean Sun itself is used as the argument in the table, the values being given for the intervals 340° −10°, 10° − 40°, 40° − 70°, 70° − 100°etc. instead of 0° − 30°, 30° − 60°, 60° −90°, 90° − 120° etc. (vide Table)

3. Quoted by Utpala on BS 2, p.40.

1a. A.हताशन

b. A.मथास्य. A1.वसुताश

c. A.हत्वा; B1.2.हचा; B3.हवा. A.क्रमादितेशो; B3.क्रमादिनेशो

d. B1.सविंशांश; D.सविंशांशः

2a. B2.दशाष्ठ

b. B.श्ययुक्ता च

c. A1.मुन्यकृतिश्च; A2.मुन्यकृतीश्च; B.मुप्तकृतश्च; C.D.मक्षकृतिश्च

d. A.समा

3a. A1.दसष°. A1. D.सप्ततिः

c. B. haplographical omission of सप्तति. A.B.तिनैका

Kendra	0°		30°		60°		90°		120°		150°	
Mean Sun	340°		10°		40°		70°		100°		130°	
Values for intervals		−11′		−48′		−69′		−70′		−54′		−26′
Real Anomaly	264°		294°		324°		354°		24°		54°	
Values taking 140′ as maximum		−12.9′		−45.6′		−67.7′		−71.6′		−56.3′		−26.0′

180°		210°		240°		270°		300°		330°		360°
160°		190°		220°		250°		280°		310°		340°
	+10′		+48′		+70′		+71′		+54′		+25′	
84°		114°		144°		174°		204°		234°		264°
	+12.9′		+45.6′		+67.7′		+71.6′		+56.3′		+26.0′	

The procedure is explained thus: According to the *Pauliśa Siddhānta* there are 120 solar revolutions in 43,831 days. So,in any desired number of days, the Sun's mean motion is days × 120 ÷ 43,831 revolutions, which multiplied by 12, 30 and 60 successively gives *rāśis*, degrees and minutes. The mean solar year begins 16½ *nāḍikās* after Epoch. Therefore to reckon days from the beginning of the year, 16½ *nāḍikās* or 33/120 days must be subtracted from the days from Epoch. As the days have already been multiplied by 120 and converted into one hundred and twentieth parts, we have to deduct 33 parts in order to deduct 33/120 days, which is the instruction.

But what is called mean Sun here is not the real mean Sun. It is the real mean Sun *plus* the equation of the centre for the beginning of the year (this makes it the true Sun) *plus* 7 minutes of arc. That it is so can be seen thus: At the beginning of the year the so-called mean Sun is zero, the Sun having made full revolutions, starting from the zero point 16½ *nāḍikās* from Epoch. The *Kendram* at that time is 0° + 20° = 20°. For this we have the difference or interval of equation of the centre, −11 × 20°/30° = −6′.67. Deducting this from *rā* 0-0-0, we have the true Sun *rā*. 11-29-53. Deducting the equation of the centre from this, the real mean Sun is got, for the true Sun is obtained by adding the equation of the centre to the real mean Sun. Thus the so-called mean Sun = the real mean Sun + the equation of the centre + 7 minutes = the real mean Sun + 142′ (135′.8 + 6′.67), the equation of the centre at this point being 135′.8 (which we shall show presently). Thus, the so-called mean Sun is practically the true Sun at the beginning of the year (the difference being only 7′) and the beginning of the mean year is therefore practically the beginning of the true year. This, we have alluded to already in verses I.11-13. Now, as this mean Sun has the same rate of motion as the real mean Sun, everywhere the difference of 142′ between them is maintained.

Now we shall verify the intervals, i.e. differences of equation of the centre. Let us assume that the longitude of the higher apsis is *rā*. 2-16-0, according to this *Siddhānta*. (As the original *Siddhānta* is lost, we cannot assert that it is so. But if the assumption works, i.e. explains everything to be explained, without leading to contradictions, then we have to take that it is correct.) This is very likely because according to the *Romaka* it is at *rā*. 2-15-0 (see VIII.2, where the instruction, "subtract (from the mean Sun) *rā*. 2-15-0 to get the *kendra* of the Sun" is given.) The *Sūrya Siddhānta*, *Āryabhaṭīya* etc. give *rā*.2-18-0 for the same; and the earlier *Pauliśa* may correctly give *rā*.2-16-0.

Now, as the intervals are for mean Sun 340° to 10°, 10° to 40° etc., we can say deducting 76°, they are for anomaly 264° to 294°, 294° to 324°, 324° to 354° etc. (See table above). Assuming the maximum

to be 140′, if the equation of the centre is computed for these anomalies, and the intervals tabulated, we get − 12.9, − 45.6, − 67.7, − 71.6, − 56.3, − 26.0, + 12.9, + 45.6, +67.7, + 71.6, + 56.3, + 26.0, in minutes. As these are not much different from the series − 11, − 48, − 69 etc., we see that our assumption about the apsis is correct and the series −11, −48, are derivable from it. In the two series, the constants are the same in some places, differ by 1′ in some, by 2′ in some, the difference being 3′ only in one place. Even this small difference may be due to the constants of the given series being empirical, the values having been discovered by repeated observations only. In this connection it may be mentioned that the tabular values of the *Romaka* differ far more than this does from the same values obtained from formula. Or it may be that the formula used for the derived series may not be full, some terms being omitted. Actually, there are such additional terms, omitted by the ancients, and works like the *Sūrya Siddhānta* give a certain correction to the epicycles which can give the equivalent of such additional terms. Thus even the small difference is explained.

Now for the additive or subtractive nature of the tabular values. They are the equivalents of what is obtained by computing the equation of the centre for the anomalies 294°, 324°, 354°, etc. and deducting the previous from the next successively. At the beginning of the year the anomaly is 284° = *rā*.9-14-0. Then the anomaly increases to 12 *rāśis*, when the Sun reaches the higher apsis, *rā*.2-16-0. As during this interval the anomaly is in the fourth quadrant, the positive equation of the centre is decreasing. Therefore the tabular values obtained by subtracting the previous from the next are negative, and given as − 11, − 48, − 69. When the Sun has crossed the higher apsis and moves 90° farther, the anomaly is in the first quadrant. Here the negative equation of the centre increases. Therefore the tabular values are again negative, and we have − 70, − 54, − 26. Then the anomaly moves in the second quadrant, where the negative equation of the centre decreases. So the tabular differences are positive and given as + 10, + 48, + 70. After this the anomaly moves in the third quadrant, where the positive equation of the centre increases. So the intervals are again positive and given as + 71, + 54, + 25. Thus, by giving the true Sun increased by 7′ as the mean and applying the two series, the first negative and the next positive, in the place of the equation of the centre, the true Sun is computed by this *Siddhānta*.

We shall now show that the equation of the centre for the beginning of the year is 135.8 minutes. The mean anomaly for the beginning of the year is 0°− 76° = 284°. Its tabular sine (see Chapter IV) 116′ 25″, multiplied by the maximum 140′ and divided by the radius 120′, gives 135.8′. It is this we used to show that the mean Sun mentioned in this *Siddhānta* is the real mean Sun plus 142′. We shall show that this is so in another way. We have seen that the mean Sun, when equal to 76°, is at the higher apsis. As the equation of the centre must be zero here, the mean anomaly being zero, the true Sun must be equal to the real mean Sun. The tabular values to be applied are, − 11′ (for mean Sun interval 340° to 10°, − 48° (for interval 10° to 40°), − 69° (for 40° to 70°) and − 70× 6°/30° (for 6° in the next internal) = − 142′. Deducting this from the mean Sun 76° we get true Sun = 73° 38′. which is also the real mean Sun. Thus we see the real mean Sun is indeed 142′ less than the so called mean Sun.

But a doubt arises: The real mean Sun of the *Pauliśa* at Epoch is *rā*. 11-27-22. But this does not agree with those of other *Siddhāntas*, as for e.g., *Saura rā*. 11-29-49, *Romaka rā*. 11-29-34, *Siddhānta Śiromaṇi*, *rā* 0-0-42. How is this difference of more than two degrees to be explained? This is the answer: Even though the *Siddhāntas* are generally agreed that longitudes are to be reckoned from the beginning of the stellar segment Aśvini (called the first point), they differ with regard to the actual point where the segment begins. So, reckoned from different points, the longitudes

naturally differ. Secondly, even if all *Siddhāntas* had started reckoning from the same point originally, the difference in the duration of their solar years would, in course of time, cause differences in longitude when computed for a particular moment of time, causing apparently a shift of the first point. Thus as the first point of the *Pauliśa* is about 2° east of that of the *Saura* or *Romaka*, the mean Sun is less, as in the case of the *Siddhānta Śiromaṇi*, which is one degree more because its first point is one degree west of that of the *Saura* or *Romaka*. It is also well-known that there is a difference of three degrees between the first point of the Caitra and Raivata Pakṣas.

Now we shall explain why 20° is added to the mean Sun to form a peculiar type of *Kendram* to give the values. Why have the values not been given directly for intervals of mean Sun, 0° to 30°, 30° to 60° etc. The reason must be that the author has taken these values from the original *Pauliśa*, or the original *Pauliśa* itself from its source, where they would have been given for intervals of mean Sun, 0° to 30°, 30° to 60° etc. But the source or original *Pauliśa's* first point might have been 10° east of that of the *Pauliśa* here given, and it might have been shifted west in course of time to the present first point adopted, (there is evidence in the Vedas of this kind of shift being made, as evident, for instance, in the case of the beginning of the year from the Sun at Mṛgaśirā to the Sun at Kṛttikā and so on) with the result that what was originally 0° had become 10°, what had been 30° had become 40° and so on reckoned from the new point. So the values are as if they are given for 340° to 10° etc. and to make them full *rāśis* for convenience, 20° are asked to be added and the name *kendram* given to it. Thus everything is properly explained.

TS have not understood the method given here. So far as the explanation of the part referring to the mean Sun goes, what they say is correct. But after that what they say is all wrong. There is the express instruction after giving the first series 11, 48 etc. that the values should be subtracted from the mean Sun. The second series 10, 48 etc. come after that in a separate sentence and a separate verse, with the instruction that the values should be added. But somehow TS have understood the two instructions to mean that the two series should first be added one to one and then the resulting new series, which they think is the equation of the centre itself, should be applied to the mean Sun. If this is done, the instruction where to add and where to subtract is lost, which they have not noted. They have failed to see that the *Siddhānta* gives differences of values for every 30° intervals of *kendram*. They have never considered why if the equation of the centre itself is given, it is given in two series which are almost identical. Again, the new series of theirs only appears to be the equation of the centre, which is because the differences of a sine-function-series is a cosine function series, which is again a sine-function-series with a lateral shift of 90° in the argument. In verifying the series they have formed by comparing it with the actual, which they have computed, they have found a difference of 6′ and 7′ in two terms, but waived them aside as negligible. But 6′ or 7′ are too large to be negligible. Further, they have failed to see that the word *kendram* is used here in a peculiar sense as we have already said. They have taken it to mean the regular anomaly. But the mean anomaly can be found only if the longitude of the higher apsis is given, which is nowhere to be found. They explain this by saying that the longitude of the apsis was well known and therefore not given! Different *Siddhāntas* give different values for the longitudes of the apsis; the *Romaka* gives 75°, the *Saura* gives 80°, and the *Āryabhaṭīya* and *Sūrya Siddhānta* give 78°. Which of these are we to take? Certain things and operations, we can understand from the context and nature of the work, but this is not a thing which can be learnt without being told, as also the instruction when to add or when to subtract the values, which, according to them, has also to be learnt otherwise. If they had only tried to work out some examples, as for instance, taking the mean Sun as 80°, using their interpretation of the rules, then they would have discovered their mistake.

[चन्द्रगतिः]

[वि]नवात् पदाद्दशघ्नात् सप्तांशः '(साऽश्विखस्वरो)' भुक्तिः ।
गत्यर्धान्ताच्छोध्यो लिप्ताभ्यो '(नवमुनिवसु-भ्यः)' ॥ ४ ॥

True Motion of Moon

4. If the *padas* obtained (by II.2) are plus-*padas*, (i.e., in the first half-*gati*) subtract 9 from the *padas*, multiply by 10 and divide by 7. Add the result to 702. The Moon's daily true motion in minutes is got. In the second half-*gati*, (i.e., if the *padas* are minus-*padas*), deduct 9, multiply by 10 and divide by 7 and subtract the result from 879. The resulting minutes are the daily true motion of the Moon.

Example 2. Find the Moon's daily true motion for plus padas 9, 18, 27, 36, 63, 71, 72, 81, 117, 124 and minus-padas 9, 63, 71, 72, 117, 124.

P = 9	daily motion	= 10 (9 − 9)/7 + 702 = 702 minutes
P = 18	"	= 10 (18 − 9)/7 + 702 = 702 + 12 6/7 = 714 6/7 minutes
P = 27	"	= 10 (27 − 9)/7 + 702 = 702 + 2 × 12 6/7 = 727 5/7 minutes
P = 36	"	= 10 (36 − 9)/7 + 702 = 702 + 3 × 12 6/7 = 740 4/7 minutes
P = 63	"	= 10 (63 − 9)/7 + 702 = 702 + 6 × 12 6/7 = 779 1/7 minutes
P = 71	"	= 10 (71 − 9)/7 + 702 = 702 + 88 4/7 = 790 4/7 minutes
P = 72	"	= 10 (72 − 9)/7 + 702 = 702 + 7 × 12 6/7 = 792 minutes
P = 81	"	= 10 (81 − 9)/7 + 702 = 702 + 8 × 12 6/7 = 804 6/7 minutes
P = 117	"	= 10 (117 − 9)/7 + 702 = 702 + 12 × 12 6/7 = 856 2/7 minutes
P = 124	"	= 10 (124 − 9)/7 + 702 = 702 + 164 2/7 = 866 2/7 minutes
P = 133	"	= 10 (133 − 9)/7 + 702 = 702 + 177 1/7 = 879 1/7 minutes
P′ = 9	"	= 879 − 10 (9 − 9)/7 = 879 − 0 = 879 minutes
P′ = 63	"	= 879 − 10 (63 − 9)/7 = 879 − 6 × 12 6/7 = 801 6/7 minutes
P′ = 71	"	= 879 − 10 (71 − 9)/7 = 879 − 88 4/7 = 790 3/7 minutes
P′ = 72	"	= 879 − 10 (72 − 9)/7 = 879 − 7 × 12 6/7 = 789 minutes
P′ = 117	"	= 879 − 10 (117 − 9)/7 = 879 − 12 × 12 6/7 = 724 5/7 minutes
P′ = 124	"	= 879 − 10 (124 − 9)/7 = 879 − 164 2/7 = 714 5/7 minutes

The daily motion when the *pada* is less than 9 cannot be found from the formula as it is, but we can frame a rule by considering the nature of the variation of motion. Minus-*padas* 1 to 8 are the successive *padas* after plus-*padas* 124 and previous to minus-*padas* 9. Therefore the motion must lie between 866 2/7 and 879, increasing from 866 2/7 (vide example). Therefore, minus-*padas* 1 to 8, multiplied by 10 and divided by 7, added to 866 2/7 will give the motion. In the same way, plus-*padas* 1 to 8 are successive *padas* after minus-*padas* 124, and before plus-*padas* 9. Therefore the motion lies between 714 5/7 and 702, decreasing gradually. Therefore plus-*padas* 1 to 8, multiplied by 10 and divided by 7 must be deducted from 714 5/7 to get the motion.

4a. A.B.C. नगात् पदात्. B1.3. दशाव्रात्
b. A.B. साश्विसांवरो; C. साश्वि [खाचला]
B1.3. भुवतिक्तिः; B2. भवनोक्तिः
c. B. गत्यर्द्धताच्छोध्यो
d. A.B.C. वसुमुनिनवभ्यः

The two rules for the true daily motion can be shown to be connected with the two rules for finding the true motion in II.6, by deriving these from those, and the exact derivation itself is a proof of the correctness of the rules. The rule for plus-*padas* (i.e. applicable to the first half-*gati*) is, $\{1094 + 5(P - 1)\}\ P/63$. If m is the mean motion at the end of the last full *gati*, then the true Moon $= m + P^\circ + \{1094 + 5(P - 1)\}\ P/63$ minutes. The daily motion of the current day is got by subtracting the true Moon at the end of the previous day from that at the end of the current day and if the *pada* is P at the end of the current day, it is P − 9 at the end of the previous day. Therefore the motion for the current day $= [m + 9^\circ + \{1094 + 5(P - 1)\} \times P/63] - [m + (P - 9)^\circ + \{1094 + 5(P - 9 - 1)\}(P - 9)/63]' = (m - m) + P^\circ - (P - 9^\circ) + \{1089 + 5P)\}\ P/63$ minutes $- \{1089 + 5(P - 9)\}(P - 9)/63$ minutes = in minutes, $540 + 1089\ P/63 + 5P^2/63 - 1089(P - 9)/63 - 5(P - 9)^2/63 = 540 + 1089 \times 9/63 + 5 \times 9^2/63 + 90(P - 9)/63 = 540 + 1134/7 + 10(P - 9)/7 = 540 + 162 + 10(P - 9)/7 = 702 + 10(P - 9)/7$. which is the rule here given.

In the same way, taking the rule for the true Moon in the second half-*gati*, i.e. for minus-*padas*, we have, the daily motion = [m + *rā*. 6-0-4 + $P^\circ + \{2414 - 5(P' - 1)\}\ P'/63$ minutes] − [m + *rā*. 6-0-4 + $(P' - 9)^\circ + \{2414 - 5(P' - 9 - 1)\}(P' - 1)/63$ minutes] = in minutes, $504 + \{2419 - 5P'\}\ P'/63 - \{2419 - 5(P' - 9)\}(P' - 9)/63 = 540 + 2419\ P'/63 - 5P'^2/63 - 2419(P' - 9)/63 + 5(P' - 9)^2/63 = 540 + 2419/7 - 45/7 - 10(P' - 9)/7 = 540 + 339\ 1/7 - 10(P' - 9)/7 = 879\ 1/7 - 10(P' - 9)/7$, which is the rule for daily motion in the second half-*gati*, omitting the small fraction of minutes 1/7. (Note that in the example we actually got this 879 1/7 as the maximum).

From the relationship between these two sets of rules shown here, we can understand that the rules for daily motion, though they have strayed into the chapter dealing with the *Pauliśa*, actually belongs to the *Vāsiṣṭha*. If they are to be used for the *Pauliśa* also, it is because they are interconnected and mixed up, as the use of the same technical terms, and the absence of the method to find the mean Moon, show, We can even say that the author does not intend this for the *Pauliśa* because another set of rules is given for this in III.9.

Because the daily increase in *padas* is 9, the daily increase or decrease in the true motion is $10 \times 9/7 = 12\ 6/7$ minutes. By integrating the motions and deducting the mean motion during the days for which the integration is done, we can find the equation of the centre implied in the rules: For convenience let us take *padas* 9, 18, etc. and work out for plus-*padas* first. The total true motion in minutes for P/9 days, i.e. to the end of P *padas* is: $702 + 10(9 - 9)/7 + 702 + 10(18 - 9)/7 + 702 + 10(27 - 9)/7 \ldots\ldots + 702 + 10(P - 9)/7 = 702 \times P/9 + 9 \times 10\{1 + 2 + 3 + \ldots\ldots (P - 9)/9\}/7 = 702\ P/9 + 9 \times 10\{\tfrac{1}{2}(P - 9)/9\}\ P/(9 \times 7) = 702 \times P/9 + 5P(P - 9)/63 = 702 \times 7P/63 + 5P^2/63 - 45P/63 = 4869\ P/63 + 5P^2/63$.

The mean motion per day can be found from 11.2–4 to be 790′ 35″ and for P/9 days, the mean motion is $790'\ 35'' \times P/9 = 5534\ P/63$ minutes. Subtracting this from the true motion found, the equation of the centre obtained is $4869\ P/63 + 5P^2/63 - 5534\ P/63 = 5P^2/63 - 665\ P/63 = (5P - 665)\ P/63$.

In the same way, we can find the equation of the centre connected with the second half-*gati*, i.e. minus *padas*. The total true motion $= 879\ 1/7 \times P'/9 - \{5P'^2/63 - 45\ P'/63\} = 6154\ P'/63 + 45\ P'/63 - 5P'^2/63$. Deducting the total mean motion, the equation of the centre $= (6154 + 45 - 5534)\ P'/63 - 5P'^2/63 = 665\ P'/63 - 5P'^2/63 = P(665 - 5P)/63$.

It is these two rules for the equation of the centre that we used in II.6, to derive the rules there. From inspection we see that $P(5P - 665)/63$ is negative for all values of P, as it ought to be in the first half-*gati*. $P'(665 - 5P')/63$ is positive, as it ought to be in the second half-*gati* for all the values of

P′. The numerical maximum is for P or P′ = 66½. For P = 124, the value is −88½ minutes which is cancelled by + 88½ minutes for P′ = 124, with the result that at the end of the *gati* the equation of the centre is zero and the true moon is equal to the mean Moon.

It is mainly because of the relationship between the rules of II.6 and those in this verse, established by using the corrected reading *vinavāt* for *nagāt* that we have made that correction. Also if we take *nagāt*, then there will be a deficiency of one syllable. The adoption of the other reading, *nāgāt* has not the fault of the defective syllable, but 9 is required in the proof and not 8. The reading *sāśvisāmvaro* is corrected as *sāśvikhasvaro*, to mean 702, which is the minimum daily motion, derivable from the rules. TS also have intended 702 minutes to be the minimum daily motion by their emendation *sāśvikhācalā*, but theirs is not likely to be the original reading with such changes in the letters. We have corrected *vasumuninavabhyah* into *navamunivasubhyah* because from the establishment of the relationship, which we did, 879 minutes is the maximum daily motion and we require this. Further, the maximum must be as far above the mean value 790½ minutes, as the minimum is below. The minimum 702′ is 88½ below 790½. So the maximum must be 790½′ + 88½′ = 879′. But TS have not touched this, for, by their own words, they have not been able to interpret this verse.

[मन्दफलम्]

पदमेकोनं 'पञ्चाष्टक' घ्न'मे(कर्तु)पक्षविषयेभ्यः' |
प्रोझ्य पदघ्नं छिन्द्या-'न्नवयममुनि'भिः कला इन्दोः || ५ ||

Equation of the centre

5. Reduce the plus or minus *padas* by one and multiply by 40. Subtract this from 5261. Multiply the result by the *padas* and divide by 729. The resulting minutes are equation of the centre.

The formula is: The equation of the centre = {5261 − 40 (*pada* − 1)} *pada*/729, where *pada* is any *pada*, plus or minus, without distinction.

Example 3. (a) Pada = 63. Find the equation of the centre. (b) Pada = 9. Find the equation of the centre.

(a). {5261 − 40 (63 − 1)} 63/729 = (5261 − 2480) 63/729 = 2781 × 7/81 = 240 1/3 minutes.

(b). {5261 − 40 (9 − 1)} 9/729 = (5261 − 320) 9/729 = 4941 × 1/81 = 61 minutes.

खार्काधिकं भवेद्यत् परिशोध्यं तत् पुनः शताद् विंशात् |
शशिनि धनं पूर्वार्धे (गत्यर्धेऽन्त्ये) क्षयः कार्यः || ६ ||

न पदं त्रिषष्टिपरतः प्रथमपदं सप्ततिं त्वतिक्रम्य |
पदयुक्ताः षट्पञ्चगुणाश्च बिन्दुस्त्रिघनभक्ते || ७ ||

5a. B.पदमेकानं
b. A.B.॰घ्नेमेकं तु पक्ष॰ (A2.॰नु पक्ष॰)
c. A.प्रोह्या; B1.3.प्रोध्या; B2.प्रोझ्या
d. B2.कलां

षष्ट्यधिकं तु यदस्मिंस्तच्छोध्यं षष्टितोऽवशिष्टं यत् |
तद्धानिः प्रथमपदे गतदलपदतः शशिनि दद्यात् || ८ ||

विनवपदैर्भुक्त्यूनैर्बिन्दुश्चन्द्रस्तदह्नि चोत्पन्नः |
तद्विश्लेशाद् भुक्तिर्नवेऽह्नि चैवं पदैः सनवैः || ९ ||

6-9. (Translation and Commentary later).

[चरः]

'विंशति'-'रष्टिः सार्धाः' 'पादोनाः सप्त' चाजपूर्वाणाम् |
विषुवच्छायागुणिताः क्रमोत्क्रमाच्च रविनाड्योऽर्धे || १० ||

Cara or Oblique ascension

10. Multiply the constants, 20, 16½ and 6¾ by the equinoctial shadow. The results are oblique ascensional differences (*carakhaṇḍas*) in *vināḍīs*, first in the given order, then in the reverse order for the first six months (solar) and again the given and reverse orders for the second half of the ecliptic, the second six months.

The differences are for the solar months Meṣa etc. in *vināḍīs*: 20, 16½, 6¾, 6¾, 16½, 20, 20, 16½, 6¾, 6¾, 16½, 20) × equinoctial shadow.

The formula for *Cara* is given in IV.26. thus: Sine *Cara* = sin latitude × sin Sun's declination × the diameter ÷ sin (90° − latitude) × the day-diameter. The sines used here are tabular sines, the

6a. B3. खार्कादिकं
b. B. परिशोध्या
C. ततः पुनः शतं विंशात्. B. विंशन्
d. A. गत्यर्द्धेत्ते; B. मत्यर्द्धे ते

7b. A1. प्रथम
B1. सप्तति-तिक्रम्य. A1. B2.3. चतिक्रम्य
c. A. परयुक्ताः; C. पद्युक्तः. A.B. षट्कं च; C. कट्पञ्चयुतश्च
d. A.B. धनाभक्ते; C. °स्त्रिष्कृतिभक्ते

8a. A1. °धिकं नु
A. यदस्मिः; B. यदवशिष्टं
c. C. तद्धानिं
d. C. गतिदल. A.C. परतः; B. पुरतः
B1.3. दषाद्यात्; B2. दृषाद्यात्

9a. C. पदे
a-b. C. भुक्त्यून इन्दुश्च [चन्] द्रस्तदह्नि चोत्तमे ।
b-c. A. चोत्पन्नैः; B. चोत्पमपदे गतदलः परस्तु तैः
तद्विधिषाद्भुक्तिनीचे चैवं
c. A. नवे चैवं; C. नीचे चैवं पदे सनवे; B. सनपैः

10. Quoted by Utpala on BS 2, p.60.
10a. A. विंशतिरष्टैः. C. सार्धा a-b. U. सार्धपादोनाः
b. B. पादोनैनाः. B1. पूर्वारिणाम्
c. B1. गुणिता
d. A. क्रोमो°; B. क्रमाच्चर. A.C. विनाड्यो र्धे; B. विनाज्योर्द्धे

unit or radius being 120′, and the diameter 240′. The day-diameter is twice the tabular cosine of the Sun's declination. Thus this formula reduces to the modern form: sin *cara* = k tan latitude × tan declination. The degrees of *cara* got from the formula, converted into minutes and divided by 3 gives the whole *cara*. The *cara-khaṇḍas* or differences are got deducting the whole *cara* of the beginning of a *rāśi* from that of the end of the *rāśi*.

We shall not derive this formula now. We shall restrict ourselves to deriving the given *cara-khaṇḍas* from the formula. The 'diameter', as we have said, is 240′ (vide IV.1). The tabular sines of declination at the ends of the three *rāśis* Meṣa, etc. is 24′ 24″, 42′ 15″, 48′ 48″ (from IV.24). The day-diameters for the same are 235′, 224′ 40″, 219′ 15″ (from IV.25). Sin latitude ÷ sin (90° − latitude) = equinoctial shadow ÷ 12. (This will be shown when dealing with IV). Therefore; successively, sine *cara* = equinoctial shadow × {(240 × 24 2/5) ÷ (235 × 12), (240 × 42 ¼) ÷ (224 2/3 × 12), (240 × 48 4/5) ÷ (219 ¼ × 12)} = Eq. shadow × (2′.08, 3′.78, 4′.45). The arcs of these cannot be found in terms of the Eq. Shadow unless it is known. But as the author intends this rule only for North India, where the eq. shadow may be taken as 6 digits on the average, we shall frame the rule for 6 and then use it for other places by the rule of proportion. So, multiplying the numbers 2′.08, 3′.78, 4′.45 by 6, we get sine *cara* = 12′ 29″, 22′ 41″, 26′ 42″. Using the tabular sines, the arcs of these = 5° 58′.3, 10° 53′.6, 12° 51′.6 = 358′.3, 653′.6, 771′.6. Dividing by 3, we get the whole *cara* in *vināḍīs*, 119.4, 217.9, 257.2. Dividing these by 6 and multiplying by Eq. shadow, we get the whole *cara vināḍīs* for any Eq. shadow, viz., Eq. shadow × (19.9, 36.3, 42.9). Deducting the next from the previous, and because the *cara* is zero for the beginning of Meṣa, as declination is zero, the *cara* differences *(khaṇḍas)* got are, Eq. shadow × (19.9, 16.4, 6.6). This is practically the same as Eq. shadow × (20, 16½, 6¾) given by the author. In the *Vākyakaraṇa, Mahābhāskarīya* and *Siddhānta Śiromaṇi*, the same method is given.

As we have said, the *cara-vināḍīs* are zero for the beginning of Meṣa when day-light is 30 *nāḍis*. Then at the end of each *rāśi*, they increase by a quantity equal to the differences, reaching a maximum at the end of Mithuna, the day-light then being a maximum also, as the declination has reached a maximum. After that the declination decreases in the same manner in which it has increased, and the day-light decreases from maximum and the *cara* also decreases. At the end of Kanyā the declination becomes zero again, the day-light equals 30 *nāḍikās* again, and the *cara* becomes zero again. So the differences have to be used in the reverse order for Karkaṭaka, Siṃha, and Kanyā. After this the South declination increases and decreases just like the North declination and corresponding to this the night-time increases from 30 *nāḍikās* to a maximum and decreases again to 30 *nāḍikās* at the end of the next six months; and the *cara* also increases from zero to a maximum and then decreases to zero, repeating what it is for North declination. Hence the instruction to repeat for the next six months of the solar year. If the *cara* is required for any day within the month, it is to be got by interpolation, which is well known and therefore not mentioned.

Example 4. (a). In a place the Eq. shadow is 5 digits. Find the cara-vināḍis when the Sun is rā.2-10-0. (b) The Eq. shadow is 7. the Sun is at the end of Tulā, find the cara-vināḍis.

(a) The constant for Meṣa is 20, for Vṛṣabha 16½ and for 10° of Mithuna, 6¾ × 10°/30° = 2¼. Adding, the total *cara* is 20+16½+2¼ = 38¾. Multiplied by Eq. shadow, the *vināḍis* are 5 × 38¾ = 193¾.

(b) The Sun is *rā*.7-0-0 and therefore 1 *rāśi* has gone in the second half of the zodiac. Therefore the *cara-vināḍis* = 7 × 20 = 140.

[अहर्मानम्]

मेषादि(षु तदु)पचि(तैः) कर्कट[का]द्येषु तदपचयमितैः ।
दिनवृद्धिस्साध्ये(त) क्षयस्तुलाद्येषु [कर्कटकात्] ॥ ११ ॥
सागरहिमगिरिपरिधौ स्पष्टमिदं चरविनाडिकाकर्म ।
अन्यत्राऽपि यथैतत् स्पष्टं तच्छेद्यके वक्ष्ये ॥ १२ ॥

Day-time

11-12. To find the day-time in Meṣa, Vṛṣabha and Mithuna, add the *cara* differences one by one, in the order given, to 30 *nāḍikās*, and in the next three, subtract in the reverse order. In the next three *rāśis*, Tulā, etc. subtract from 30 *nāḍis* in the given order, and for Makara etc. add in the reverse order. This will give the day-time fairly accurately for places in Northern (whole?) India. I shall give the method to find the day-time accurately in other places (in the IV chapter) when dealing with spherical astronomy.

Thus, when the Sun is in the six *rāśis*, Meṣa, etc. 30 *nāḍikās cara-vināḍis* = day-time. When in the six rāśis, Tulā etc. 30 *nāḍikās cara-vināḍis* = day time. The increase over 30 *nāḍikās* and the decrease to 30 is by Eq. shadow × {20, 16½, 6¾, 6¾, 16½, 20}*vināḍis*. This is repeated in the decrease from 30 *nāḍis* and the increase to 30, in the six *rāśis* from Tulā. We shall explain all this in the IV chapter.

The *cara-vināḍis* computed in the above manner and the day-time got by them will be accurate only in Northern (whole?) India it has been said. The reason for this is as follows: From the explanation of the method of computing the *cara-vināḍis*, it can be noted that sine *cara* is proportionate to the Eq. shadow, and the *cara-vināḍis* are proportionate to the arc obtained from sine *cara*. It is well known that when the sines are small they are proportionate to their arcs. Therefore when sine *cara* is fairly small, i.e. when the Eq. shadow is small, the arcs are proportionate to the Eq. shadow, i.e. the *cara-vināḍis* are proportionate to the Eq. shadow. In India the Eq. shadow is fairly small, and therefore the *cara-vināḍis* for different places in India can be formed by proportion, using the Eq. shadow. In higher latitudes like places North of the Himalayas, the shadow increasingly becomes greater, and the inaccuracy of using the given method will gradually increase.

Example 5. (a) Eq. Shadow 5, Sun rā. 2-10-0. Find the day-time. (b) The Eq. shadow is 7, the Sun is in rāśis 7. Find the day light.

(a) The *cara-vināḍis* are 5(20 + 16½ + 2¼) = 5 × 38¾ = 194. As the Sun is in the 6 *rāśis*, Meṣa etc., the day-time is greater than 30 *nāḍis*, and, therefore, the day-time is 30 *nāḍis* + 194 *vināḍis* = 33-14 *nāḍis*.

11a. A.B. मेषादिषडुपचितं (B2. ॰षट॰; B2. चित्तं)
b. A.B. कर्कटाद्येषु. C. ॰षु[च] तद. A. चयमितै
c. A.B. साद्येने; C. स्याद्येन
d. B. तुलाद्यैष्टुकु. A.C.D. ॰षु वैषुवतात्; B. ॰षु वैषुवनात्

12a. A1. हिमापरि थौं; A2. B1.C. हिमाद्रिपरिधौ; B2.3. हिमद्रिपरिधौ
c-d. A2. यथैतस्पष्टं; B2.3. तथैतत्
d. A1. तछेद्यके

(b) The *cara-vināḍis* are 7 × 20 = 140. The Sun being within the 6 *rāśis* from Tulā, the day-time is less than 30 *nāḍis*. Therefore the day-time is 30 *nāḍis* − 140 *vināḍis* = *nāḍis* 27-40.

[देशान्तरम्]

यवनान्तरजा नाड्यः सप्ताऽवन्त्यां त्रिभागसंयुक्ताः ।
वाराणस्यां 'त्रिकृति': साधनमन्यत्र वक्ष्यामि ॥ १३ ॥

Deśāntara

13. The correction to the time of the longitude of Yavanapura to get the time of the longitude of Ujjain is seven *nāḍikās*, 20 *vināḍikās* and that of Banaras (Vārāṇasi) is nine *nāḍikās*. How to find the correction for other longitudes will be given (in the next verse).

In short, what is here given is the difference in time due to difference in longitude alone from Yavanapura of Ujjain and Banaras, *Deśāntara-nāḍis*, being difference in time of the occurrence of any event due to longitude, the occurrence being earlier by this time if the place is East, and later if West. Actually the time difference due to longitude for Ujjain from Yavanapura is *nāḍis* 7-38, and for Banaras, *nāḍis* 8-50. The Greenwich East Longitude of Yavanapura, Ujjain and Banaras are 30°, 75° 50′ and 83°. From this we can find the actual time difference: (75° 50′ − 30°)/6 *nāḍis* = 7-38, (83° − 30°)/6 *nāḍis* = 8-50. But considering the difficulty of doing this faced by the ancients for want of facilities, the achievement of the *Siddhānta* is commendable.

'त्रिकृति'घ्नात् 'खवसु'हृताद् योजनपिण्डात् स्वताडिताज्जह्यात्
अक्षद्वयविवरकृतिं मूल्याः षट्कोद्धृता नाड्यः ॥ १४ ॥

14. Take the distance in *yojanas* between the two places between which the time difference for longitude has to be found. Multiply this by 9 and divide by 80. (The result is their distance in degrees). Square the result. From this deduct the square of the difference in latitude between the two places. Find the square root of the remainder. (This is the East-West difference in degrees). This divided by 6 is the time difference in *nāḍikās*.

The purpose of finding this time difference is ultimately to find the time difference for longitude from Yavanapura, so that it may be used in the reduction of the planet found for Yavanapura mean sunset to the local sunset. If by this rule, the time difference from Ujjain or Banaras is found, then

13a. A. यवनात्तरजा; B1.3. युवनाच्चरनाड्यः
b. A.B1.2. वन्त्यास्त्रिभाग
c. B2. वाणारस्यां
d. A1. साधमन्यत्रः A2. साधनमत्पत्र

14a. A. त्रिकृतिघ्ना खवसु
b. A. पिडात्; B1.2. पिण्डाश्वता°; B3. पिण्डश्वता°
A.B. °ता जह्यात् (B3. जह्यत्)
c. A.B. विवरक्रति
d. A.B.2. मूलाः; B1.3. मूल्याः; C. मूलं
A1.B. षट्कोधृता; D. षट्कोद्धृतं

by adding or subtracting this, according as the place is East or West, to or from *nāḍis* 7-20 (for Ujjain) or 9-0 (for Banaras), respectively, the time difference for longitude from Yavanapura can be got.

Example 6. The latitude of a place west of Ujjain is 27° and the distance between them is 44 4/9 yojanas. Assuming the latitude of Ujjain to be 24°, find the time difference for longitude of the place from Yavanapura.

The distance in degrees = 9 × 44 4/9 = 5°. The difference in latitude in degrees is 27° − 24° = 3°. $\sqrt{5^2 - 3^2} = 4$ = the east-west difference in degrees. 4/6 *nāḍikās* = 40 *vināḍikās* is the time difference. As the place is West of Ujjain, deducting this from 7-20, the time difference from Yavanapura is *nāḍikās* 6-40.

The rule is explained thus: It is well known that in a plane right-angled triangle the square of the hypotenuse is equal to the sum of the squares of the sides containing the right angle. Now, let the places be P_1 and P_2. Let the point where the line of longitude passing through one of the places, say P_1, cuts the latitude passing through the other say P_2, be C. Then C is practically a right angle of which CP_1 is one arm and CP_2 the other, and P_1P_2 is the hypotenuse of the right angled triangle P_1CP_2. If P_1P_2 is not too great, then this triangle, though on the surface of a sphere, may be treated as practically a plane triangle. P_1C is the difference in latitude of the places. P_2C is the difference in longitude, which is wanted. P_1P_2 is the distance between them. We are going to find the difference in longitude P_2C in degrees. The difference in latitude P_1C is also in degrees. So P_1P_2 also must be found in degrees. So the distance in *yojanas* is converted into distance in degrees by multiplying the *yojanas* by 9 and dividing by 80, because according to this *Siddhānta* there are 9° for 80 *yojanas* on the Earth, i.e. the circumference of the Earth (360° if given in degrees) is 3200 *yojanas*. Thus we have the difference in longitude in degrees $= CP_2^2 = \sqrt{P_1P_2^2 - CP_1^2}$. The degrees are converted into time by the proportion, if there are 60 *nāḍikās* for 360° of longitude, how much for the degrees got. Therefore degrees got × 60/360 = degrees got/6, are the *nāḍikās* of difference in longitude.

In view of the right angled triangle not being exactly plane, a better result will be got if the *nāḍikās* obtained are multiplied by the circumference of the earth and divided by the circumference of the line of latitude midway between the places. But the author has not mentioned this because this method is intended for India and in India the two circumference do not differ much and therefore the difference between the two methods will be negligible. *Sūrya Siddhānta* etc. give the correct method. The author's method is given by the *Mahābhāskarīya* with the name *Adhvā* ('Path') and by the *Vaṭeśvara Siddhānta* with the name '*Adhvavaha*' ('Marching on the Path'), only to be condemned as inaccurate. In the *Vākyakaraṇa*, which is also satisfied with rough results, the distance along the latitude (CP_2 in the explanation) is taken as found and a rule given. The method of determining the latitude of a place is given in IV.20-21 and the author expects us to get it by using that method and use it in the formula.

Another thing must be mentioned here. If the two places are distant from each other or intervened by a sea or mountain or some such obstacle, as for instance Yavanapura and Ujjain, Yavanapura and Banaras, or Ujjain and Banaras, then by observation, from the two places, of celestial phenomena that are visible everywhere at the same moment, like the circumstances of a lunar eclipse, the time difference for longitude can be obtained. (All *Siddhāntas* give methods based on this principle, and the *Mahābhāskarīya* in Chapter II, which is, devoted exclusively to *Deśāntara*, gives two methods.) The following is the method: Let us assume that the meridian of Ujjain as the prime meridian (generally given in all *Siddhāntas* do) and by computation it has been found that at 5 *nāḍis* after midnight the total obscuration of the moon begins. (The beginning or end of the

total phase can be observed well and therefore specially chosen by the *Sūrya Siddhānta*). In another place, say in Banaras, the beginning of the total phase is observed to be at *nāḍikās* 6-12, (of course by its own time, i.e. local time). The time difference for longitude must be patently the difference between the two times, i.e. *nāḍis* 6-12 minus *nāḍis* 5, i.e. nā. 1-12. As the local time must increase as we go east, we can also say that Banaras is east of Ujjain.

[इष्टदेशास्तकालः]

देशान्तरनाडीभ्य-श्चरनाड्यर्धं क्षयस्तु पूर्वाऽर्धे |
चक्रस्याऽर्धे चान्त्ये वृद्धिस्तद्भोगमपि जह्यात् || १५ ||

Local Sunset time

15. If the Sun is in the six *rāśis* Meṣa etc., subtract half the *caravināḍis* from the time difference for longitude. If the Sun is in the six *rāśis* Tulā etc. add half the *cara-vināḍis* to the time difference for longitude. Find the motion of the planet (the Sun or Moon, in this context) during this time. Subtract this from the longitude of the planet computed. (The planet for the beginning of the local day, i.e. for local sunset, is obtained).

Example 7. The time difference for longitude at a place (in India) with reference to Yavanapura is 10 nāḍis. The Sun is rā. 9-0-0 and the cara for that day at the place is 4 nāḍis. The Moon computed is rā. 4-8-0 and its daily motion 840′. Find the Moon at the beginning of the local day, i.e. at local sunset of the place.

Longitude time difference = 10 *nāḍis*. Half *cara* = 4/2 = 2, *nāḍis*. As the Sun is within the six *rāśis* from Tulā, adding 10 and 2, we get 12 *nāḍis*. The motion per day is 840′. The motion for 12 *nāḍis* is, 840′ × 12/60 = 168′ = 2° 48′. Subtracting from the computed Moon, the Moon at local sunset is, rā. 4-8-0 − 2° 48′ = rā. 4-5-12.

The explanation of the procedure is as follows: As the days from Epoch are from mean sunset at Yavanapura, the planets computed for the days from Epoch are for mean sunset at Yavanapura and if they are required for any time in the day, they have to be found by adding the motion during the time. Therefore if the planets are required for local sunset at any other place, the time interval between the local sunset and Yavanapura mean sunset has to be found first, and the motion for the interval applied to the planet computed. This motion is subtractive if local sunset is earlier, and additive if later.

Now, the author intends the procedure for India alone, and at places in India the local sunset is always earlier than Yavanapura mean sunset. This is because nowhere in India (including Afghanistan) is the difference for longitude from Yavanapura less than 4½ *nāḍis*, and the half *cara* greater than this. Because India is east of Yavanapura in the local mean sunset is earlier by the time difference for longitude. The actual sunset is earlier than the mean sunset or later by half the *cara-nāḍis*. It is later if the Sun is in the six *rāśis*, Meṣa etc., because the day-time is longer. It is earlier if the Sun is in the six *rāśis*, Tulā etc. Therefore the local actual sunset is earlier than Yavanapura mean sunset by the time difference for longitude *minus* half the *nāḍis* of *cara* when the daytime is greater. But

15a. A. नादीभ्य; B. नाडीम्य
b. C. नाड्यर्धक्षय°. B. पूर्वार्द्धम्
c. B. विक्रस्यार्द्धे
d. B. वृक्षि. B. भोरामपि; D. भागमपि

as the half *cara* is always less, there is always a remainder when this subtraction is made by which time, therefore, local sunset is always earlier. When the Sun is in the 6 *rāśis*, Tulā etc., the local sunset is earlier by the time difference for longitude and still earlier by the half *cara*. Therefore it is earlier by the sum of the two. Thus, in all cases, with regard to places in India, the sunset is earlier than the mean sunset at Yavanapura and therefore the motion for the time is always to be subtracted; and, that is the instruction.

If the place is north of India or west, it may happen that the half *cara* is greater than the time difference for longitude. Then when the Sun is in the six *rāśis* from Meṣa, the sunset may be later and the motion for the later time will have to be added to the planet. Further, there are two other corrections, *Bhujāntara* (correction for the Equation of the centre) and *Udayāntara* (Reduction to the Equator), the equivalent of the *equation of time* which have got to be made, but not given by this *Siddhānta* either because these are very small or because this *Siddhānta* is not aware of its existence. The *Vākyakaraṇa* omits to give the *Udayāntara* alone because it is not found even in its source, *Bhāskarīya*. The *Sūrya Siddhānta* omits the *cara* and *Udayāntara* corrections, the former because it begins the day at midnight which is not affected by *cara* and the latter because it is not aware of its existence. Śrīpati is the first to give the Udayāntara.

TS are unaware that the two corrections mentioned above are given here, which can be seen from the commentary pp. 12-13, and English notes pp. 16-17. They also seem to think that the instruction to subtract or add is for places in the northern and southern hemispheres, respectively. (cf. Skt. com., p. 13). NP, too, have not got the sense fully, for they observe on this verse: "A fragmentary passage which in the present form makes no sense, e.g., because one cannot add longitudinal differences and ascensional differences." (Ch. II, p. 31).

[नक्षत्रानयनम्]

ऋक्षं लिप्ता[ष्ट]शती व्यर्काच्चन्द्रात्तिथिर्द्विषट्कांशैः ।
भुक्त्यनुपाताद्वेला रवीन्दुभुक्त्यन्तराच्च तिथेः ॥ १६ ॥

Nakṣatra computation

16. For every 800 minutes of arc in the Moon's longitude there is one *nakṣatra* (asterismal segment). Deduct the Sun's longitude from the Moon's. For every twelve degrees of the remainder there is one *tithi*. The time of the ending moment of the *nakṣatra* should be found by proportion using the Moon's daily motion. The time of the ending moment of the *tithi* should be found by proportion, using the difference in the daily motions of the Sun and the Moon.

The idea is this: Compute the Moon's longitude for the end of the day on which the *nakṣatra* is to be found, and also the motion for the day. Convert the longitude into minutes and divide by 800. The quotient are the *nakṣatras* gone, and the last of them is the *nakṣatra* ending in the day, before the incomplete one began. Multiply the remainder by 60 and divide by the daily motion in minutes.

16a. B1.3.रुक्षं; B2.रुक्षे. A.लिप्ताथती; B.लिप्ताशती
b. A.तिथिद्वि॰; B1.2.॰च्चन्द्रतिथिद्वि॰
c. B1.3.भुन्ननुपाता
d. B.रावीन्दु

The result are *nāḍis* of the incomplete *nakṣatra* gone in that day. Deduct it from 60. The ending moment of the *nakṣatra* gone or last gone on that day is got in *nāḍis* from the beginning of the day.

To get the *tithi*, subtract the Sun's longitude from the Moon's and convert it into minutes. Divide by 720. The quotient are full *tithis* gone after new moon. The last *tithi* gone is the *tithi* ending before the incomplete one begins. Multiply the remainder by 60 and divide by the difference of the Sun's and Moon's motions in minutes, for that day. The result are *nāḍis* of the incomplete *tithi* on that day. Deduct the *nāḍis* from 60. The remaining *nāḍis* are the ending moment of the *tithi* ending or last ending on that day. If the total *tithis* got are more than 15, count again from one, i.e. *Prathamā*.

Example 8. At the end of a certain day the Sun is rā. 2-15-10 and its daily motion 57′. The moon is rā. 10-18-30 and its daily motion 827′. Find the nakṣatras etc. for the day.

The Moon = *rā*. 10-18-30 = 318° 30′ = 19,110′. Dividing this by 800 the quotient, i.e. full *nakṣatras* gone is 23, and the remainder 710′ has gone in the 24th. Multiplying by 60 and dividing by the daily motion, 710 × 60 ÷ 827 = 51-31, *nāḍis*, belong to the 24th. Therefore the 23rd, i.e. Śraviṣṭhā ends 60.0 − 51.31 = 8.29 *nāḍis*, after the beginning of the day.

The *Tithi:* Moon − Sun = *rā*. 10-18-30 − *rā*. 2-15-10 = *rā*. 8-3-20 = 243° 20′ = 14,600′. Dividing by 720, the full *tithis* gone are 20, and the remainder 200′ has gone in the next *tithi*. Multiplying this by 60 and dividing by the difference of the daily motions, the *nāḍis* got are 200 × 60 ÷ (827 − 57) = 200 × 60/770 = 15-35, which is the time occupied by the 21st *tithi*. Therefore the 20th *tithi*, i.e. Bahula Pañcamī ends at 60 *nāḍikās* – 15.35 *nāḍikās*, i.e. 44.25 *nāḍikās* after the beginning of the day.

The length of a *nakṣatra* is 800′ and the Moon's mean daily motion 791′, is not much different from it. The length of a *tithi* is 720′ and its mean daily passage 732 is not very much different from it. Therefore generally there is one *nakṣatra* or one *tithi* ending in a day. But it may happen that the remainder is so small and the motion or passage for the day so great, that, remainder + length of a *nakṣatra* or *tithi* < the daily motion or passage. In this case, two *nakṣatras* or two *tithis* end on the same day. In the case of the *tithi* this is called *avama*, the second ending *tithi* being immersed in the day and not counted for reckoning days. On the other hand, the remainder may be greater than the motion or passage for the day, with the result that no *nakṣatra* or *tithi* ends on that day, i.e. they begin at close of the previous day, extend throughout the day and end at the beginning of the next day. When this happens in the case of a tithi it is called *Tridina-spṛk*, literally 'touching three days'.

The explanation of the rules is as follows: The Zodiac consists of 12 *rāśis*, i.e. 12 × 30 × 60 = 21,600 minutes. It is divided into 27 equal segments called *nakṣatras* and so there are 21600 ÷ 27 = 800 minutes for each segment. What is called *nakṣatra* in the verse and sought to be found, is the *segment* in which the Moon is situated. Therefore the Moon's longitude in minutes is divided by 800 and the quotient are the segments passed. The remainder is the position of the Moon in the next segment. The time taken by the Moon to pass that portion is found by the proportion; If the daily motion takes 60 nāḍikās to pass, how long will the remainder take? Therefore the time when the Moon has been at the end of the segment just passed, i.e. the end of the *nakṣatra* passed, falls before the end of the day by the obtained *nāḍikās*.

Now for *Tithi*: When after new moon the Moon leaves the Sun behind for every 12° one *tithi* is gone. Therefore by subtracting the Sun from the Moon, the total degrees left behind is found, and dividing this by 12° or 720′ the *tithis* gone is found. Everyday, i.e. in every 60 *nāḍikās*, the Sun is left behind by the difference of their motions. Therefore the time taken for leaving behind the remainder is: remainder × 60 ÷ difference of the motions. As the remainder is of the incomplete *tithi*, the completed *tithi* ends before the end of the day, by a time equal to the *nāḍikās* found.

[रविमुक्तिः]

'[यम]-शिखि-गुणा-ऽग्नि-यम-शशि'-'वियुता सैका सरूप रूपै-का'
'खै'-'क'वियुता च भानोः षष्टिर्भुक्तिः क्रमादेवम् ॥ १७ ॥

Sun's daily motion

17. The daily motion of the Sun in minutes during each of the twelve months, Meṣa etc. is 58, 57, 57, 57, 58, 59, 61, 61, 61, 61, 60, 59.

The daily motion for the month is found thus: During every solar month, the Sun moves one *rāśi*, i.e. 1800′. Dividing this by the days of the month the daily motion is got. Or, according to the length of the month, take 31, 30 or 29 days of the month, almost covering it. Find the motion for these days and divide by the number of days taken, the daily motion for the month is got. Because the daily motion thus found is very near sixty minutes, the author enumerates their difference from sixty, for the sake of convenience.

The mean daily motion is 59′ 8″, which can be got dividing the minutes in 12 *rāśis*, i.e. 21,600, by the days in the solar year. Because the higher apsis, i.e. the apogee of the Sun, is about the middle of Mithuna, the Sun's motion in Vṛshabha, Mithuna and Karkaṭaka is very slow, and the daily motion, 57′ given for these is proper. Because the lower apsis, i.e. the perigee, is about the middle of Dhanus, the Sun's motion in Vṛścika, Dhanus and Makara is very quick, and the daily motion, 61′ given for these is proper.

We shall hẹre derive the motion for Meṣa and Tulā. Let us begin with the moment on the first day of Meṣa, when the mean Sun is zero. By III.1, the *kendram* is 20° and the correction for making the Sun true is − 11′ × 20°/30° = − 7′. The true Sun is 0°−7′ = *rā.* 11−29−53. 31 days after this moment, the mean Sun is, 31 × 120 ÷ 43831 × 360° = 30° 33′. The *kendram* is 30° 33′ + 20° = 50° 33′. The true Sun is 30° 33′ − 11′ − 48′ × 20° 33′/30 = *rā.* 0-29-49. The motion of the Sun for 31 days is *Rā.* 0-29-49 − *rā.* 11-29-53 = *rā.* 0-29-56. The motion per day is 29° 56′/31 = 1736′/31 = 58′. Therefore 58′ is the correct motion for Meṣa and not what is mentioned in the given verse, and that is why we have suggested the emendation *yama* for *guṇa* in the text.

We shall examine the daily motion for the Tulā. We shall begin work from the first day of Tulā when the mean Sun is 185°. The *kendram* for that is 185° + 20° = 205°. The true Sun is 185° − 11′ − 48′ − 69′ −70′ − 54′ − 25′ + 10′ × 25°/30° = 180° 31′. Now we shall take a time 30 days later. The mean Sun then is 185° + 30 × 120 × 360°/43831 = 214° 34′. The *kendram* is 214° 34′ + 20° = 234° 34′. The true Sun is 214° 34′ − 11′ − 48′ − 69′ − 70′ − 54′ − 48′ − 25′ + 10′ + 48′ × 24° 34′/30° = 210° 46′. The motion for 30 days is 210° 46′ −180° 31′ = 30° 15′. The motion per day is 30° 15′ ÷ 30 = 60½′. The author gives this as a whole number, 61′; so it is all right.

17a. A.B.C.D. गुण
b. B. वियुक्ता
A.C. खैर्क for सैका
c. C. भानां
d. C. क्रमाद् [भानोः]

[करणानि]

सित (बहुलयोः) क्षयधनं षड्भागाश्शीतगो रविभोगात् |
लिप्ताः 'खर्तुहुताशैर्लब्धं करणं तिथिवदन्यत् || १८ ||
बहुलचतुर्दश्यर्धाद् ध्रुवाणि शकुनिश्चतुष्पदं नागः |
किंस्तुघ्नमिति [च] करणान्यर्धे (चराणि) प्रवर्तन्ते || १९ ||

Karaṇas

18. In the bright fortnight take the Moon *minus* Sun and subtract from it 6°. For the dark fortnight (take the Moon *minus* Sun from the beginning of the dark fortnight, i.e.) take the Moon *minus* Sun with 6 *rāśis* subtracted from it, and add 6°. Convert it into minutes and divide by 360′. What are obtained are the *(Cara) karaṇas* (Bava etc. coming one after another repeatedly). (Take the remainder and treat it as) the remainder in calculating the *tithi*, (i.e., multiply by 60, and divide by the difference of the daily motions of the Sun and Moon in minutes etc.) (and thus get the ending moment of the last *karaṇa*. In each *tithi* the first half is one *karaṇa* and the second half another).

19. From the middle of the fourteenth *tithi* of the dark fortnight (are the four half *tithis*, viz., the second half of Bahula-Caturdaśī, the two halves of Amāvāsyā, and the first half of Śukla-pratipad, which) are the *Sthira-karaṇas, Śakuni, Catuṣ-pāda, Nāga* and *Kiṃstughna,* respectively. (The other *Karaṇas* are) movable. A *karaṇa* is half a *tithi.*

Then from the remaining half of sukla-pratipad the *Cara-karaṇas* come in the order Bava, Bālava, Kaulava, Taitila, Gara, Vaṇijya (Vaṇija) and Viṣṭi (Bhadra), (repeating eight times).

As said before, there are two *karaṇas* in a *tithi,* the first ending at the middle of the *tithi*, and the second ending with the *tithi*. Therefore, the ending moment of the second need not be computed separately. Even that of the first is not computed by almanac-makers, the mid-point of the *tithi* being taken for this. Another thing is to be mentioned: Just as two *tithis* can end on the same day, three *karaṇas* can end on the same day.

Example 9. Calculate the karaṇā from the data supplied in Example 8.

Moon − Sun got there is *rā*. 8-3-20, and the difference of daily motion 770′. As it is Bahula-pakṣa, deducting 6 *rāśis* and adding 6°, *rā*. 8-3-20 − *rā*. 6-0-0 + 6° = *rā*. 2-9-20 = 4160′. Dividing by 360′, the quotient got is 11, and remainder 200′. As in the case of the *tithi*, the ending moment is : 200 × 60 ÷ 770 = nā. 15-35 before the end of the day, i.e. the *karaṇa* ends *nā*. 44-25 after the beginning

18a. A. सितवज्जलधोः; B1. सितवजलधेः;
B2.3. सितवनुलधेः
b. A.B. भागोविरवि. A. भोगान्
19a-B. B1.3. बहुलयतु द्दश्यं द्धधि वाणि;
B2. बहुलचतु दृश्यं तां द्वयध्रुवाणि
b. A1. °श्रवष्पदं; B. °नि चतुष्पदं
c. A. °घ्रामिति; B. °घ्रासित
c-d. A.B.C. चराण्यर्धे; D. चराण्यर्धं
d. A.B. करणानिवत् प्रवर्तन्ते;
C. करणानि प्रवर्तन्ते;
D. करणं तिथेः प्रवर्तन्ते

of the day, and the *karaṇa* that has ended, being the 11th, is Taitila. (Note that this is also the ending moment of the *tithi*).

In the place of *vajjaladhoḥ* (in verse 18) the reading *bahulayoḥ* is suggested, following the meaning and keeping to the letters. Or, it can be corrected as *kajjalayoḥ* which will give the same meaning, 'dark fortnight'. Secondly, to avoid splitting the word *ardhe* between the third and fourth feet (in verse 19), *carāṇi* and *karaṇāni* have been interchanged, as possibly the scribe has interchanged them by the similarity of letters. The word, *ca* is interposed in the third foot, to make up the deficiency of one syllable, as an original *ca carāṇi* might possibly have been written as *carāṇi*. The extra syllable in the fourth foot can be explained in the manner we did earlier.

[व्यतीपातवैघृती]

अर्केन्दुयोगचक्रे वैधृतमुक्तं दशर्क्षसहिते (तु) |
यदि च(क्रं) व्यतिपातो वेला मृग्या (युतैभोगैः) || २० ||

Vyatīpāta and Vaidhṛta

20. When the sum of the true longitudes of the Sun and the Moon equals one complete revolution, (i.e., twelve *rāśis*) there is the *yoga* called *Vaidhṛta*. When this sum *plus* ten *nakṣatras* (i.e., *rāśis* 4-13-20) equals a complete revolution, (i.e., twelve *rāśis* or twenty-four *rāśis*), then is the *yoga* called *Vyatīpāta*. Their time is to be found by using the sum of the daily motions of the Sun and the Moon.

The *yogas* are found thus: The true Sun and Moon are computed for the ending moment of every day. When the sum of these is a little over 12 *rāśis*, during that day the end of the *Vaidhṛta* will occur. ('A little over' means, not more than the sum of their daily motions). When the sum plus *rā*. 4-13-20 is, in the same way, a little over 12 *rāśis* or 24 *rāśis*, the ending moment of the *Vyatīpāta* will occur during that day. The ending moments must be found like the ending moments of *nakṣatras* mentioned already, using, in the place of the daily motion of the Moon, the sum of the daily motions of the Sun and the Moon.

Example 10. (a) At the ending-moment of a day the true Sun is 2' 20° and the true Moon 9^r 15°. Their daily motions for the day are 57° and 783' respectively. Show that Vaidhṛta will occur on that day, and find its ending moment.

The sum of the true longitudes is 12^r 5°. This is a little, i.e. 5°, over 12 *rāśis*, (5° being less than 57′ + 783′). Therefore *Vaidhṛta* will end on that date. The ending moment is when the sum is exactly 12 *rāśis*, i.e. the sum is less by 5° or 300′. Therefore, the ending moment is $300 \times 60 \div (57' + 783')$ = *nā*. 21-26 earlier than the end of the day, i.e. *nā*. 38-34 from the beginning of the day.

(b) At the ending moment of a day, the true Sun and Moon are: 9^r 15° 20′ and 10^r 7° 20′, respectively, and their daily motions 61′ and 749′. Show that Vyatīpāta ends on that day and find the moment.

The sum of the true Sun and Moon = 19^r 22° 40′. The sum plus 4^r 13° 20′ = 24^r 6° 0′. This is more than a full revolution by 6° which is less than the sum of the daily motions, 61′ + 749′ = 13° 30′. Therefore *Vyatīpāta* ends on the day. The ending moment is: $360' \times 60 \div (61' + 749')$ = *nā*. 26-40, before the end of the day, i.e. *nā*. 33-20 from the beginning of the day.

20a. C. योगषट्के
b. A. दद्यर्क्ष. A.B.C. सहितेषु; D. सहितस्तु
c. A1. चक्रे; B.C.D. चक्रो. D. व्यतीपातो
d. A.B. मृग्या पितैर्म्मागैः; C. मृग्या गतैर्म्मागैः; D. मृग्यार्पितैर्म्मागैः

The author here gives the computation of two of the twenty-seven yogas, *Viṣkambha*, etc., of which *Vyatīpāta* is the seventeenth and *Vaidhṛta* is the twenty-seventh. These have to be known because offerings are made to the manes and other deeds of merit are performed at these times, as at Viṣuva, Ayana, Saṅkrama, etc. (which also are going to be given), these being two well-known days among the ninety-six Śrāddha-days. All astronomers know that the twenty-seven *yogas* are computed like the twenty-seven *nakṣatras*, using the sum of the true Sun and Moon in the place of the true Moon and the sum of the daily motions in the place of the Moon's daily motion, because the *yoga* and the *nakṣatra* have equal extent, viz. 800 minutes. *Vaidhṛta*, the twenty-seventh of the *Viṣkambha* series, and the *Vaidhṛta* here given are identical because the one ends at twenty-seven *nakṣatra* segments, i.e. one full revolution, and the other also ends at a full revolution, the duration of both being the same. In the same way, the *Vyatīpāta* given by the author is the same as the seventeenth *yoga* of the same name in the *Viṣkambha* series because, true Sun + true Moon + 10 *nakṣatra*-lengths = one revolution = 27 *nakṣatra*-lengths. Therefore true Sun + true Moon = 27 − 10 = 17 *nakṣatra*-lengths, given for *Vyatīpāta* of the *Viṣkambha* series.

For the sake of syntax *sahiteṣu* has been corrected as *sahite tu*. For the sake of grammar *cakraḥ* is corrected as *cakram*, for the neuter gender alone means a cycle or revolution, viz. 12 *rāśis*. Or let it be the masculine *cakraḥ* itself, meaning collection which ultimately can yield the idea of a collection of 12 *rāśis*. *yitair bhāgaiḥ* is corrected as *yutair bhāgaiḥ*, i.e. 'the sum of the daily motions', which is necessary. *Gatairbhāgaiḥ* or *sthitair bhāgaiḥ* can satisfy the context, but will not be sufficient, for division by the sum of the daily motions cannot ordinarily be understood without being told. But the correction, of *cakre*, which is quite all right, as *ṣaṭke* by TS is unwarranted and due to ignorance of what is wanted here.

Another thing must be mentioned. If the twenty-seven *yogas*, *Viṣkambha* etc., are computed, as in the later-day works like the *Sūrya Siddhānta*, then there would be no need to take the trouble of computing these two, viz. the seventeenth and the twenty-seventh, alone separately. If we are instructed to do these two separately, it is because the *Pauliśa* did not have the twenty-seven *yogas*. We have reason to believe that even during the time of the VM these did not exist, for in the *Bṛhatsaṃhitā*, while *nakṣatra*, *tithi* and *karaṇa* are taken up for astrological predictions *yoga* is not so taken.

The following is the history of the *yoga*. The *yoga* is not mentioned in the Vedas, and the *Vedāṅga Jyotiṣa* does not give it. From the *Paitāmaha* condensed by our author we can infer that the original *Paitāmaha Siddhānta* gave the *Vyatīpāta* for the first time, for this condensed *Paitāmaha* gives the rule for *Vyatīpāta*: "Multiply the days from Epoch, (this Epoch is different), by 12, and divide by 305" (XII. 8). In the Bauddha and Jain astronomical works, like *Sūryaprajñapti* and *Kālalokaprakāśa*, too, the *Vyatīpāta* alone is mentioned. Because the author gives both *Vyatīpāta* and *Vaidhṛta* here, we can guess that the original *Pauliśa* had *Vaidhṛta* also. Āryabhaṭa, a contemporary of VM, mentions *Vyatīpāta* alone in the *sūtra*, "The Sun's cycles plus the Moon's cycles are the number of *Vyatīpātas*" (*ABh*, *Kāla*. 3,), but commentators take him to mean *Vaidhṛta* also by implication, for, the *Mahābhāskarīya*, which is practically a commentary on the *Āryabhaṭīya* says, "When the Sun *plus* the Moon equals six signs it is the *Vyatīpāta*, when it is twelve signs it is *Vaidhṛta*, and when it is equal to the distance of Anūrādhā it is the yoga *Sārpamastaka*" (IV. 35). Here the sum being equal to twelve signs, gives the *Vaidhṛta* mentioned in the context, which is patent. The distance of Anūrādhā being equal to seventeen *nakṣatra* segments, *Sārpamastaka* is to be identified with the *Vyatīpāta* of the *Pauliśa*, which, as we have shown, is the seventeenth of the *Viṣkambha* series. Govindasvāmi too, in his *Mahābhāskarīya-Bhāṣya* on this verse quotes the original *Āryabhaṭīya-Sūtra* and explains that Bhāskara here gives both *Vyatīpāta* and *Vaidhṛta*. (As for the *Vyatīpāta* given by the sum equal to six signs, that

is the *Mahāvyatīpāta*, distinct from the seventeenth of the *Viṣkambha* series, which is not what we are talking about here.)

Prabhākara, generally mentioned as a disciple of *Āryabhaṭa*, has mentioned seven *yogas*, which he called *Mahādoṣaḥ* ('the great Inauspicious'). This information we have from two *ślokas* quoted by *Śaṅkaranārāyaṇa* in his commentary on the *Laghubhāskarīya* as Prabhakāra's. The *ślokas* say, "Find Sun *plus* Moon, in terms of *nakṣatra*-segments. When they are equal to twenty-seven (i.e. a full revolution), when 14, 8, 12, 5, 17, 18 and 10 are added, there are the *Mahādoṣas Nirodha, Parigha, Vajra, Daṇḍa, Gaṇḍa Śūla* and *Vyatīpāla*, respectively. In this group, all excepting *Daṇḍa*, can be identified in the Viṣkambha series. Prabhākara has not included *Vaidhṛta* in the group, perhaps because he does not consider it as a *Mahādoṣa*. Because these are computed individually, by a special rule, we can conclude that the twenty-seven yogas, *Viṣkambha* etc., were not in vogue in the days of Prabhākara. We have mentioned that in the days of Bhāskara a senior contemporary of Brahmagupta, also the twenty-seven *yogas* did not exist. Though it may be supposed that the twenty-seven *yogas* had come into vogue by Brahmagupta's days from the statement, "The minutes of the sum of the longitudes of the Sun and the Moon, divided by 800 are the yogas", (*Br. SpSi., Spaṣṭa*. 63) and on the strength of this we ourselves have written that Brahmagupta knew the twenty-seven *yogas,* in our Introduction to the *Mahābhāskarīya*, it is now learnt that the statement is an interpolation because this is not taken up and commented upon by *Pṛthūdakasvāmi* in his *Bhāṣya* of the *Brāhmasphuṭa-Siddhānta* and also because in giving the computation of *puṇyakālas* at the ends of *tithis, nakṣatras*, etc. according to custom, like Vaṭeśvara and Śrīpati, Brahmagupta omits *yoga* while the others include *yoga* as well. In the *Sūrya-Siddhānta* etc. which are later, the *Viṣkambha* series find a place. Thus of the five *aṅgas*, the *yoga* was the last to develop.

We said that the *Vyatīpāta* was the first *yoga* born and next *Vaidhṛta*. We shall consider their nature and how they arose. The Vedic priests and astronomers were in the habit of observing the sky looking for celestial occurrences like the rising and setting of the Sun and the Moon, because of the need of this kind of knowledge for the performance of *yajñas* and out of thirst for knowledge. It is said that the *Gavām-ayana Satra* was designed for this very purpose. The following facts were observed by them. At one time the Sun rises farthest south of the East point, that is the end of *Dakṣiṇāyana* and beginning of *Uttarāyaṇa*. (This is the winter solstice). After that, the Sun rises more and more north every day and, at the end of six months, rises farthest north. Then is the end of *Uttarāyaṇa* and the beginning of *Dakṣiṇāyana*. (This is the summer solstice). From that time it begins to rise more and more to the south, until after six months again it is farthest south. This is the end of *Dakṣiṇāyana* and the beginning of *Uttarāyaṇa* again. Thus in a year there are the two courses of the Sun, northward and southward. In a given place, the exact point north or south where the Sun rises depends on its declination north or south. Like the Sun, the Moon too, according to its declination, rises north or south of the east-point and has its *Uttarāyaṇa* in about fourteen days and its *Dakṣiṇāyana* in about the same period, the total taking a little more than twenty-seven days. Now, the day on which the Sun and the Moon rise almost at the point, one moving south-ward, and the other moving north-ward, coming to meet each other as it were, that day is the *Vyatīpāta*. Because they cross each other moving in *different* directions, the phenomenon is called *Vyatīpāta* or *Vyatipāta*.

Now, how can the time of the phenomenon be computed? Because they must rise nearly at the same point, their declinations must be nearly equal. That they must be moving in opposite directions, i.e. their respective *ayanas* should be different, has been mentioned. These two conditions can be approximately secured if the position of one is as far away on one side of the junction of *Uttarāyaṇa* and *Dakṣiṇāyana*, as that of the other is on the other side of the junction. Let us take it that the

longitudes are reckoned from the starting point of the *Uttarāyaṇa* (winter solstice), as in the *Vedāṅga Jyotiṣa* and the *Paitāmaha* from *Śraviṣṭhā*. The two being at equal distances on both sides of the zero point means that the sum of their longitudes is equal to one full revolution, i.e. twelve *rāśis*. It is this that the *Paitāmaha* gives by its rule, 'Multiply the days by twelve and divide by 305.' But, because the true declination of the Moon will generally differ from that of the Sun at this time, on account of its latitude, the time given is only approximate and the *Paitāmaha* intends that the actual time should be found by observation.

If we reckon the longitude not from *Śraviṣṭhā* as the zero point but from *Aśvinī*, then the longitudes will each be five *nakṣatras* less, because *Aśvinī* is five *nakṣatras* forward, and the sum will be ten *nakṣatras* less. Therefore, if ten *nakṣatras* are added to the sum of the longitudes (as the author asks us to do) we have the condition fulfilled, and therefore the *Vyatīpāta*. But in course of time, on account of the precession of the equinoxes, the winter solstice had moved to the beginning of Makara at the time of the author, and now still more backward so that conformity to definition is growing less and less. But on account of respect for the old *Śāstras*, the 17th continued and still continues to be the *Vyatīpāta*, just as we continue to observe *Uttarāyaṇa* rites still when the Sun enters Makara because *Uttarāyaṇa* was once there, though now it has come down into Mūla. A new type of *Vyatīpāta* called the *Mahāvyatīpāta* came into existence to satisfy the definition. This is mentioned by the author in the next two verses.

The memory of a sacred day at the sum being a full revolution resulted in the creation of a new sacred day, even when reckoned from *Aśvinī*, and it was called *Vaidhṛta*, because the old *Vyatīpāta* was 'sustained' (*dhṛta*), as it were, by this. Because it has grown in the place of the *Vyatīpāta*, this *Vaidhṛta* itself is sometimes called *Vyatīpāta*. For e.g. the *Sūrya-Siddhānta* says, "This is another well known *Vyatīpāta*, called by the different name of *Vaidhṛti*" (XI. 8) and "The three fearsome *Vyatīpātas*" (*XI. 22*). Govindasvāmi also says this: "When the sun *plus* Moon is equal to six signs, there is *Vyatīpāta*. When it is equal to twelve signs it is *Vaidhṛta* and this is also called *Vyatīpāta*; for it is said 'The sum of the revolutions of the Sun and those of the Moon are the *Vyatīpātas* (in the yuga)' (*ABh*. Kāla, 3)." How does this mean that? This is how: The *sūtra* primarily gives only the *Vaidhṛtas* that come at the end of full revolutions, which are called *Vyatīpātas* because both have the same characteristics. The effect of both being the same, *Vaidhṛta* is called *Vyatīpāta*. So the *vyatīpātas* characterised by full revolutions and half revolutions are both given by the *sūtra*. (Govindasvāmi's *Bhāṣya, Mahābhāskarīya* IV.35). Śaṅkaranārāyaṇa too, by saying "Āryabhaṭa mentions the two types of *vyatīpātas*", in his commentary on *Laghubhāskarīya*, II. 29, understands *Vaidhṛta* also by the word *Vyatīpāta*.

आश्लेषार्धादासीद् यदा निवृत्तिः किलोष्णकिरणस्य ।
युक्तमयनं तदाऽऽसीत् सांप्रतमयनं पुनर्वसुतः ॥ २१ ॥

21. When the Sun began to turn south, i.e. when the summer solstice was at the middle of the asterism, Āśleṣā, the requirement of the definition that the Sun and the Moon should be in different ayanas was satisfied. But now the turning south takes place at three quarters of Punarvasu. Therefore the definition has become faulty.

From this we can infer that the author knew the precession of the equinoxes. In the *Bṛhatsaṃhitā* also he says the same thing, "Certainly at one time, the summer and winter solstices were at the middle of *Āśleṣā* and the beginning of *Dhaniṣṭhā*, respectively, because such has been mentioned in

the ancient lore. But now the summer solstice is at the beginning of Cancer and the other one at the beginning of Capricorn. If at any time this is not conformed to, then there is a further change, which can be seen and measured by observation and examination." (*Br. Sam.* III. 1-2). It is from this that we have interpreted Punarvasu as "the point at three quarters of Punarvasu". The ancient lore mentioned here includes *Vedāṅga-Jyotiṣa* and *Paitāmaha Siddhānta*. The *Yājuṣa-Jyotiṣa* says, "At the beginning of Śraviṣṭhā the Sun and the Moon turn northward and at the middle of Āśleṣā they turn southward, with the Sun always in the Māgha and Śrāvaṇa months, respectively" (verse 7). "When the Sun and the Moon rise in the sky together, with Śraviṣṭhā with them, the Yuga begins then as also the month of Māgha, the seasonal month Tapas, the bright fortnight, and the turning northward " (verse 6). As the *Paitāmaha* too counts the *nakṣatras* of longitudes from *Śraviṣṭhā* and says that it is *Vyatīpātā* when the sum of their longitudes is a whole revolution, we can infer that the turning northward is at *Śraviṣṭhā*.

विपरीतायन(या)तो यदाऽर्ककाष्ठां श(शी) सविक्षेपः ।
भवति तदा व्यतिपातो दिनकृच्छशियोगचक्रार्धे ॥२२ ॥

22. With the Moon approaching to meet the Sun, moving in a direction opposite to that of the Sun, when its true declination (i.e. the mean declination plus its latitude) becomes equal to the Sun's and when the sum of their longitudes is nearly six signs, then is the *Vyatīpāta* conforming to the definition, (i.e. the *Mahāvyatīpāta*).

The minimum and sufficient conditions for the *Mahāvyatīpata* are that the Sun and Moon should have different southward or northward courses and that their true declinations must be equal, both being north or both being south. The second part of the second condition, though not mentioned by the verse, is implied in the requirement that the sum should be nearly six signs. Because the northward or southward courses and the declinations depend on the tropical longitudes, we can understand that the sum also is of the tropical longitudes (i.e. the *sāyana* longitudes) of the Sun and the Moon. If this is not stated it is because during the time of the author the *Ayanāṁśa*, i.e. the difference between the tropical and sidereal longitudes, was practically zero and the author intended the work as a *karaṇa* not to be used for a very long time when the *ayanāṃśa* would become considerable.

We have interpreted "half revolution as approximately six signs" because when the Moon has a latitude as generally it would have, the equality in declination will happen not exactly at the sum being six signs. Only the mean declination of the Moon will be equal to that of the Sun when the sum is exactly six signs, as Bhāskara I says in his commentary on the *Āryabhaṭīya*, (*Kāla*, 3), "*Vyatīpāta*

21. Quoted by Utpala on BS 2, p.40.
21a. A1.B1.2. अश्लेषार्घा॰
b. B. किलोकृकिरणस्य
c. A. युक्तमथनं
d. A. ॰तमथनं

22a. A.B.D. ॰यनपातो C. ॰यनभागो
b. B. पदार्क A.B. शशिसविक्षेपः
B. काष्टांशशि; C.D. काष्ठांश [श] शिरविक्षेपः
c. B. भवेति
d. A. दिनक्रच्छशि

occurs when the declinations are the same and the courses are different. The expression half-revolution in that connection is only meant to be approximate, because by the latitude of the Moon it may be a little more or less." Therefore we should examine whether a *Vyatīpāta* would occur at the neighbourhood of the sum being six signs, because it can occur only there. But sometimes it may not occur at all, because the definition is not satisfied (All this is expounded clearly in works like the *Siddhānta Śiromaṇi* and we stop with this).

One may think that we are making contradictory statements by saying in the history of the origin of the *Vyatīpāta*, that it occurs at the sum being full revolutions and here that it occurs at half revolutions. There is no contradiction because the origin from which the longitudes are measured is different in the two cases. In the former the winter solstice was taken as the origin, and, in the latter, the spring equinox. There is a difference of three signs between the origins, which causes the same difference in each of the two longitudes, with the result that there is a difference of six signs in the sum. That they are the same can be shown thus: The Sun measured from winter solstice, (say, *a*) = the Sun measured from spring equinox (say, *b*) + 3 signs. The Moon measured from winter solstice, (say, á) = the Moon measured from spring equinox (say, b́) + 3 signs. Therefore a + a′ = b + b′ + 6 signs. If a + a′ = full revolution, b + b′ + 6 signs = full revolution, therefore b + b′ = full revolution − 6 signs = half revolution, which proves the sameness. Spring equinox is not mentioned because at the author's time it was situated at the beginning of *Áśvinī* and lõngitudes are reckoned from there.

Example 11. The Sun and the Moon at the end of the day are rā. 1-10-0 and rā. 4-23-30, and their daily motion 57′ and 783′. Taking the spring equinox to be at the beginning of Aśvinī, i.e. the winter solstice at the beginning of Capricorn, examine the possibility of Vyatīpāta, in both ways.

Because the longitudes are from zero *Aśvinī*, they are the same as reckoned from spring equinox also, both points being the same in the problem. Therefore sum of longitudes = rā. 1-10-0- + rā. 4-23-30 = *rā.* 6-3-30. This is 3° 30′, i.e. 210′, over a half revolution. The sum of the daily motions = 57′ + 783′ = 840′. Therefore at 210 × 60 ÷ 840 = 15, *nādis* before the end of the day, the sum is equal to a half revolution or 6 signs, and so *Vyatīpāta* may occur in its neighbourhood.

Otherwise, if the longitudes as measured from winter solstice, the Sun = *rā.* 1-10-0 − *rā.* 9-0-0 = *rā.* 4-10-0. The Moon = *rā.* 4-23-30 − *rā.* 9-0-0 = *rā.* 7-23-30. Their sum = *rā.* 4-10-0 + *rā.* 7-23-30 = *rā.* 12-3-30, and this is 210′ over a full revolution. Therefore 210′ × 60 ÷ 840 = 15, *nāḍis* before the end of the day. The sum is a full revolution and the *Vyatīpāta* may occur as its neighbourhood. (Note that worked in both ways, the time is the same).

Now for the readings. In the place of *pāto* we have taken *yāto* because the scribe may easily mistake *pā* for *yā*. But the correction *bhāgo* of TS does not agree with the second case in *arkakāṣṭhām* and deserves to be rejected. The wrong reading, *śaśi-savikṣepaḥ* has been corrected by us into *śaśī savikṣepaḥ*, by a simple lengthening of. But TS and NP have made it *saśiravikṣepaḥ* which is incorrect and also does not agree with *kāṣṭhām*. The meaning which they have taken for this verse itself is wrong. Their interpretation of *kāṣṭha* into 'maximum declination' i.e. 24° (or 23° 20′) is not proper, for, in his work (see Chap. IV), *kāṣṭhānta* is used for maximum declination and *kaṣṭhā* is taken to mean only declination. Let us concede it is maximum declination and therefore means 24°. Even this does not agree with the meaning given by them because they want and imply 23° 20′ only there. If 24° is given roughly for 23° 20′, why not 23° which is nearer. They do not seem to have understood at all what is sought to be conveyed by the author.

[षडशीतिपुण्यकालः]

मेषतुलादौ विषुवं षडशीतिमुखं तुलादिभागेषु |
षडशीतिमुखेषु रवेः पितृदिवसा ये(ऽव)शेषाः स्युः || २३ ||
षडशीतिमुखं कन्याचतुर्दशेऽष्टादशे च मिथुनस्य |
मीनस्य द्वाविंशे षड्विंशे कार्मुकस्यांशे ||२४ ||

Ṣaḍaśīti-puṇyakāla

23-24. At the first point of Meṣa (Aries) and Tulā (Libra) are the spring and autumnal equinoxes (and the sacred days thereof are when the Sun is there.) The commencements of the sacred days called *Ṣaḍaśītis* are at periods of 86 solar degrees commencing with *Tulā*-zero point. The days in the solar months after the respective commencement of the *Ṣaḍaśītis* are sacred as connected with the manes. The commencement of the *Ṣaḍaśītis* are after 14 degrees of Kanyā, (Virgo), after 18 degrees of Mithuna (Gemini), after 22 degrees of Mīna, (Pisces) and after 26 degrees of Dhanus (Sagittarius).

The main purpose of the author in giving the equinoxes here is to indicate the sacred days connected with them as can be gathered from the context. The equinoxes, i.e. the points of intersection between the ecliptic and the celestial equator, though moving westward slowly along the ecliptic, (this is the precession of the equinoxes), were at the first points of Meṣa and Tulā only at the period of the author. At the present day the equinoxes have moved far into Uttara-Bhādrapada and Uttara-Phalgunī, but the sacred days are still observed with the Sun entering Meṣa and Tulā by blind routine.

The time taken by the Sun to move one degree is a 'solar day' according to Hindu astronomers. (We have put it within inverted commas, because in English it means the ordinary day caused by the Sun and therefore quite different). So in a solar year there are 360 'solar days', and in each solar month 30 'solar days'. As for counting from zero-Tulā, this is enjoined by the *Dharma-śāstras*. The commencements of the *Ṣaḍaśītimukha-s* are, $1 \times 86° = 86°$, $2 \times 86° = 172°$, $3 \times 86° = 258°$ and $4 \times 86° = 344°$. from zero-Tulā, i.e. from *rā.* 6-0-0. Therefore they are *rā.* 6 + 86°, *rā.* 6 + 172°, *rā.* 6 + 258° and *rā.* 6 + 344°, and these are, respectively, 26 degrees of Sagittarius, 22 degrees of Pisces, 18 degrees of Gemini and 14 degrees of Virgo. These sacred days are not observed in these days and it would be interesting to know when and how they went out of vogue. When the Sun enters Sagittarius, Pisces, Gemini and Virgo, we observe the sacred day, calling it *Ṣaḍaśīti*; and in the place of the last sixteen 'solar days' of Virgo, (these seem to have secured importance at the time of *Sūrya Siddhānta*) the dark fortnight of Bhādrapada is dedicated to the Manes, with the name of *Mahālaya-pakṣa*. The dark fortnight of Āśvina also is observed as a secondary *Mahālaya-pakṣa* and it is the belief that the Manes are sent back to their world on *Naraka-Caturdaśi*. Now, what is the speciality about 86 solar days, it may be asked. This period is three synodic months less one day. It may be

23a. A. मेखतुलादौ A. विषुव; B.1.2. C.D. विषुवत्; B3. दिषु
b. A. षडसीति
c. A.B. दिवसाद्ये
d. A.B. विशेषा स्युः
24b. A. ०ष्टादर्शे

that a section of people observed a sacred day for the manes once in three synodic months, and then this came in its place.

[अयनम्]

उदगयनं मकरादावृतवः शिशिरादयश्च सूर्यवशात् ।
द्विभवनकालसमानं दक्षिणमयनं च कर्कटकात् ॥ २५ ॥

Solstices

25. The Sun's turning northward is when it reaches the zero-point of Makara, (Capricorn), i.e. at winter solstice, and its turning southward is at the zero point of Karkaṭaka (Cancer) i.e. at summer solstice, with the attendant sacred days. The seasons *Śiśira* etc. commence with the winter solstice and each season lasts two tropical solar months.

The precession of the equinoxes implies the precession of the solstices as well and therefore the solstices at the zero-points of Karkaṭaka and Makara is true only for the period of the author. If the sacred days are observed still when the Sun enters these signs, it is again blind custom.

As the seasons depend upon the position of the mid-day Sun in the sky and the length of day time, and these depend on the Sun's declination depending on tropical (*sāyana*) longitude of the Sun, the seasonal months are different from either the solar sidereal months Meṣa etc. or the synodic months Caitra etc., and these cannot correctly represent the seasons. That is why the Vedas give a new set of months, (actually tropical months) for the seasons: Madhu and Mādhava are the months constituting the *Vasanta* (spring) season, Śukra and Śuci are the months constituting the *Grīṣma* (summer season), Nabha and Nabhasya are the months constituting the *Varṣa* (rainy) season, Iṣa and Ūrja are the months constituting the *Śarad* (post-rainy season); Sahas and Sahasya constituting the *Hemanta* (pre-winter) season; and Tapas and Tapasya constituting the *Śiśira* (winter) season. (Śuklayajurveda, 13.25). Even in the *Vedāṅga Jyotiṣa* we have the information that the *Śiśira* season begins with the *Uttarāyaṇa* (winter solstice). The *Yājuṣa-Jyotiṣa* (verse 6) says, "When the Sun and the Moon rise together, with Śraviṣṭhā, from then commence the *yuga*, the month of Māgha, the seasonal month Tapas, the light fortnight of the month, and *Uttarāyaṇa*". As Tapas is the first month of *Śiśira* we understand *Śiśira* begins with *Uttarāyaṇa*. By mentioning Māgha and Tapas distinctly, we understand that the Vedas wish us not to confuse the two. But confusion there has been, and still continues, with the result that people call Meṣa and even Vṛṣabha spring months, though patently we have summer then, Kumbha and Mīna being practically the spring months now. This confusion has resulted in Madhu, Mādhava etc. and Caitra, Vaiśākha etc. as synonyms. People who know are amused, when in the *saṅkalpa* recited for Hindu rituals the month of Vṛṣabha, which is advanced summer, is mentioned as spring.

[संक्रान्तिकालः]

षष्टिघ्ना भुक्तिहृता रविबिम्बकला भवन्ति नाड्यस्ताः ।
संक्रान्तीनां कालः पुण्योऽतोऽर्धेन चाद्यन्तात् ॥ २६ ॥

25. Quoted by Utpala on BS 2, p.23.
25a. A.B1.मकरादौ
b. A.वृत्तकशिशि; B1.2.वृवृंतकशशि
c. U.समाना

Saṅkrānti-kala

26. The angular diameter of the Sun in minutes, multiplied by sixty and divided by the daily motion of the Sun, are total sacred *nāḍis* of Saṅkrānti (literally 'crossing'). Half this time before and after the Sun entering a *rāśi*, is sacred.

The *Pauliśa* does not give the angular diameter of the Sun, so it must be the intention of the author to use the angular diameter given by the *Romaka* or the *Saura*.

Example 12. The angular diameter of Sun is 31′ and its daily motion 57′. The Saṅkramaṇa is 19 nāḍis after sunrise. Find the sacred nāḍis.

Angular diameter × 60 ÷ daily motion = 31′ × 60 ÷ 57′ = *nā*. 32-38. Half this is 32-38/2 = *nā*. 16-19. Therefore *nā*. 19-0 − *nā*. 16-19 = *nā*. 2-41 to *nā*. 19-0 + 16 − 19 = *nā*. 35-19 is the sacred period.

The rule is proved thus: The time of the centre of the Sun's orb crossing to the next sign is the time of *Saṅkramaṇa*. At this time half the orb is in the previous sign and half in the next. The period when parts of the orb are in both signs is the sacred period. So it begins when the east point of the orb just enters the next sign and ends when the west point just leaves the previous sign. So, during the interval the Sun moves a distance equal to its own diameter. This time is got by the proportion: daily motion: angular diameter :: 60 *nāḍikās*: the required time. Therefore aṅg. diameter × 60 ÷ 60 is the time in *nāḍikās*. As half this time is required for the mid-point to reach the junction of the signs, half this period placed on either side of the time of the mid-point crossing over gives the beginning and end of sacred period.

It must be noted that if the angular diameter is computed according to the old Hindu astronomical works and used, the sacred period would be constant whatever be the daily motion, and the sacred period can easily be given as so many *nāḍikās* before and after *saṅkramaṇa*. How? Let *x* be the mean angular diameter in minutes. According to Hindu astronomy the angular diameter is proportionate to the daily motion, (because the motion is taken inversely proportionate to the distance and the angular diameter also is inversely proportionate to the distance) (See VIII. 15, IX 14-16). Therefore the angular diameter = *x* multiplied by daily motion ÷ mean daily motion. The period = angular diameter × 60 ÷ daily motion = *x* × daily motion × 60 ÷ (daily motion × mean daily motion) = *x* × 60 ÷ mean daily motion which is constant. If to avoid this we assume that the mean diameter is intended to be used in the rule, then the rule is unreasonable. Or we have to accept it on the injunction of the *Dharmaśāstras*, throwing the burden on them. We said, "according to the old Hindu astronomical works", because actually the angular diameter is not exactly proportional to the daily motion.

[त्रिदिनस्पृग्योगः]

तिथ्यन्तं यदि सूर्यः स्पृशन्नुदेत्ये(षा) वासरं चाऽपि |
योगस्तदा त्र्यहस्पृक् तिथित्रयस्पर्शनाद(वमः) || २७ ||

26a. B1. भुक्षिहताः B2. भुक्षिहता; B3. भ्रुक्षिहता
b. A1. रबिम्ब॰; B. बिम्बककला
d. B1.2. पुण्यतोद्धैन
For चाद्यन्तात्, B1.2. वार्धता कृतिः; B2. न नार्धत्तात्

Tridinaspṛg-yoga

27. When a *tithi* extends throughout a day, coinciding with a part of the previous day and the next day, the occurrence is called *Tridinaspṛg,* (literally 'touch of three days'). (If, besides a whole *tithi,* parts of the previous and next *tithis* fall on the same day, the occurrence is called *avama*, literally, 'uncounted *tithi*').

The only thing we have done to the reading in the first half of the verse is to change *śā* into *ṣā*, which is quite warranted. But TS have changed *de* into *di* and introduced a new word, *anya*. Still their reading of the text cannot yield the meaning. To agree with *tithitraya-sparśañat*, we corrected *ahnaḥ* into *avamaḥ*, because *avama* alone results by contact with three *tithis*. The word *ahnaḥ* is necessary also, but can be understood from the context, though not mentioned, but not so, *avamaḥ*. If this part is left uncorrected as TS have left, the expression would be non-sensical like Sudhākara's meaning: "Because the day touches three *tithis*, it is called 'Three-day touching'. But Thibaut has grasped the idea here, though calling it "the conjunction touching three *Tithis*". NP too, have caught the idea, but since the relevant emendation to *avama* did not strike them, they merely say '(there is a yoga)'."

[राहुः]

अष्टगुणे दिनराशौ 'रूपेन्द्रियशीतरश्मि'भिर्भक्ते |
लब्धा राहोरंशा भगणसमाश्च क्षिपेल्लिप्ताः || २८ ||
वृश्चिकभागा राहोः षड्विंशतिरेकलिप्तिकालुप्ताः |
आदिरतः प्रोह्य मुखं षड्राशियुतं तु पुच्छाख्यम् || २९ ||

Rāhu (Node)

28. Multiply the days from Epoch by 8 and divide by 151. Rāhu's motion is got in degrees etc. Add minutes equal to revolutions. (The motion becomes exact.)

29. Deduct the motion from $7^r\,25°\,59'$. The remainder is Rāhu's Head (what is called Dragon's Head, a popular name for the Ascending Node). Add 6 *rāśis* to Rāhu's Head, (Dragon's Tail or Descending Node), is got.

Example 13. (a) Days from Epoch, 75,500; find Rāhu's Head and Tail. (b) Find the Head of Rāhu at Epoch, i.e. for Zero day.

27b. A. स्पृश्यन्नु; B. स्पृशेतु॰
A. ॰देतोशावासरं; B. ॰देत्येशावांसरः; D. ॰न्नुदेत्येष्यं
C. ॰दितोन्यवासरं
c. B. ॰स्तदत्र्यहः B. स्पृक
d. A.B.C.D. नादह्नः ||
28a. A2.B. गुणो. B. गुणाशशौ
b. B. ॰भिव्यक्ते
c. A2. लबध्वा. B. शहोरंशा
d. A2. क्षिपेलिप्ताः; B1. क्षिपेछित्रप्ताः
29b. A. विशति. C.D. लुप्ता
c. B. आदियरत. B1.2. प्रोज्य; D. प्रोज्झ्य. B. मुख
d. A2. युतं नु. B2. पुच्छाक्ष्यं

(a). Rāhu's motion for 75,500 days = 8 × 75,500 divided by 151, degrees = rev. 11-1-10-0. The exact motion = rev. 11-1-10-0 + 11 minutes = rev. 11-1-10-11 = *rā.* 1-10-11, omitting full revolutions. Rāhu's Head = *rā.* 7-25-59 − *rā.* 1-10-11 = *rā.* 6-15-48. Tail = *rā.* 6-15-48 − *rā.* 6-0-0 = *rā.* 0–15–48.

As the motion of Rāhu is zero, the Head of Rāhu is the constant itself, viz. *rā.* 7-25-59.

As the motion is 8° in 151 days, according to this *Siddhānta*, to move 360°, i.e. one revolution, it takes 360 × 151 ÷ 8 = 6795 days. But during this period it moves one minute more, i.e. the exact motion is 360° 1′ in 6795 days, i.e. one revolution takes 360° × 6795 ÷ 360° 1′ i.e. 6794 days, 19 *nāḍis*.

We have seen that the Head of Rāhu for the Epoch, according to the *Pauliśa* is the constant itself, viz. *rā.* 7-25-59. According to the *Saura* (condensed by the author) it is *rā.* 7-26-6. According to the *Vākyakarana* it is *rā.* 7-26-11. According to modern astronomy, taking the *ayanāṃśa* as being zero for the period it is *rā.* 7-26-0. According to the *Siddhānta Śiromaṇi* it is *rā.* 7-27.13. We see that all except the value of *Śiromaṇi* agree closely, verifying the *Pauliśa* value for the Epoch. The disagreement of the *Śiromaṇi* value is only apparent, for the zero point of the *Śiromaṇi* zodiac is about one degree behind that of the rest, (as may be seen by comparing with its co-ordinates of the stars or from its Sun being one degree more than that of the rest) and if the same point is taken as the origin, the *Śiromaṇi* too gives about *rā.* 7-26-13.

Thus the value at epoch is necessary to get the Rāhu at any moment, and it is this that is given by *Vṛścikabhāgā Rāhoh* etc. But TS have not understood this need (as they did not understand the need for the *kṣepa* in the case of the Moon (see II.3) and gave a wrong interpretation of *śaśimuninava-yamāśca rāśyādyāḥ*) and give the following laughable explanation: "The measurement of the limbs of Rāhu having the form of a scorpion is 25 minutes. Deducting this from the motion of Rāhu obtained from (28), the head or face of Rāhu is to be found. This plus six *rāśis* is the tail. We have to rely only on the words of the ancients to know that the scorpion-like limbs of Rāhu measure 25 minutes, there is no other reason." Now we ask: Let it be that they have not understood the need for the *kṣepa*. How did it not occur to them that Rāhu can be got only by deducting the motion from something, whether it is a cycle or some other constant, because the motion is retrograde (as they themselves have said in other places: "Rāhu deducted from a full revolution is the Head, this plus six *rāśis* is the tail", IX. 6, "deducted from the end of Pisces is the head", VIII. 8). It also appears here that Thibaut is not satisfied with Sudhakara's explanation. Further, how did it not occur to them that *ekaliptikāluptāḥ ṣaḍviṃśativṛściakabhāgāḥ*, means *rā.* 7-25-59, when they have correctly interpreted *siṃhasya vasuyamāṃśāḥ* as (XVI. a) *rā.* 4-28-0, *sārdhāḥ pañcālino* (XVIII. 1) as *rā.* 7-5-30, *nava sārdhāḥ kanyāṃśāḥ* (XVIII. 11) as *rā.* 5-9-30, *ṣodaśa vṛṣabhasyāṃśāḥ nava liptikāvarjitāḥ* (XVIII. 18) as *rā.* 1-15-51? It is really astounding what tricks the mind can play!

Incidentally, the following should be mentioned here for general information. Following the nomenclature of the ancient *Saṃhitās*, the author calls the ascending node Rāhu's head, and the descending node 'Rāhu's Tail', both being Rāhu, though generally in later astronomical works the word *Pāta* is used. In recent times, somehow the term Ketu has come to be applied to the descending node, Rāhu being retained for the ascending node, though there is no authority in astronomical works or *Purāṇas* to bring in Ketu here. The ancient *Saṃhitās* use the term Ketu for the Dhūmaketus or comets and, as deities they are generally referred to in the plural. They are also characterised by unpredictable motions and in the *Bṛhatsaṃhitā* too the author says so. (This is the view of the ancients though we now know that a number of them are periodic, and their positions can be predicted with tolerable accuracy). They are worshipped in the collective, as seated on doves,

with the expression, "Salutation to the Ketus." From the singular in the *mantra* of their invocation, *Ketum kṛṇvannaketave,* one may think that Ketu is referred to in the singular also. It is not so. Here the word does not mean the 'Comet' Ketu at all. The *mantra* itself is in praise of the Sun and Ketu here means the activity caused by the Sun in the sleeping inactive world. How then is this *mantra* used to invoke the Ketus? The utterance of the word Ketu here is sufficient, as the utterance of the many *śa* sounds in the Mantra *śaṃ no devīḥ* etc. (*Ṛgveda* 10.9.4) is sufficient to propitiate Śanaiścara. though the *mantra* itself refers to the water-deities, or the utterance of the word *mayūra* in the *mantra, āmandrair intra haribhiḥ* etc. (*Ṛgveda* 3.45.1) is sufficient to propitiate Subrahmaṇya, though the *mantra* refers to Indra, as also words like, *Om, atha kalyāṇa* etc. cause auspiciousness by their mere utterance. So, according to the *Sāstras,* Ketu refers only to the Dhūmaketus, and Rāhu is both the nodes, the recent application of the term Ketu to the descending node being unwarranted. Therefore, when the *Dharmaśāstras* enjoin the eclipses caused by Rāhu as sacred periods, they take in both the ascending and the descending nodes, and the suggestion by some that they do not take in the descending node on the score of some un-informed people calling it Ketu is wrong because what they call Ketu is really Rāhu.

[चन्द्रविक्षेपः]

वक्त्रादधिकश्चन्द्रो हीनः पुच्छाच्च याति भगणोदक् |
हीनो वदने पुच्छे-ऽधिकेऽ(सु)राद्याति दक्षिणतः || ३० ||
भागनवत्या राहोश्चन्द्रोऽन्तरितोऽतिमहति विक्षेपे |
लिप्ताशतद्वये[ना]त्यशी(त्याऽ)नुपातोऽतोऽन्यत्र || ३१ ||

Moon's latitude

30. If the Moon lies between the Head and the Tail it is north of the ecliptic, (i.e. its latitude is north). If it lies between the Tail and the Head it is south of the ecliptic, (i.e., latitude is south).

31. The latitude is a maximum equal to 280 minutes when the Moon is 90 degrees distant from either Head or Tail. The latitude is to be found by proportion, at other places, using the distance in degrees from Head or Tail, whichever is nearer.

Example 14. The true Moon is rā. 2-7-0. Rāhu's Head is rā. 5-3-0. Find the latitude of the Moon.

The Tail is Head + *rā.* 6-0-0- = *rā.* 11-3-0. The Moon is between Tail and Head. Therefore the latitude is south. The distance of the Moon from the nearer limb, Head is *rā.* 5-3-0 − *rā.* 2-7-0 = *rā.* 2-26-0 − 86 degrees. For 90° the latitude is 280′. For 86° latitude is $86° \times 280' \div 90° = 267\frac{1}{2}'$, South, as seen.

30a. B. चक्रादधिक
b. A.B1. पृच्छाच्च. B. ॰पोदृक्
c. A1.B1. पुछे; C. वदनात् पुच्छाधिको
d. A.B. ॰धिकोमुराद्याति; C. ॰धिकोऽसुराद्याति; D. धिकोऽमुकाद्याति

31b. B. ॰तोभिमहति
c-d. A. येत्यशीतिमनुपातोन्यत्र ।;
B. द्वयेत्यशीतमुनुपातोन्यत्र ।;
C. द्वयाधिकसप्ततिरनुपाततोन्यत्र ।;
D. द्वय[मे]त्यशीतिमनुपातोतोन्यत्र |

The rule is explained thus: The Moon moves in its own orbit, inclined to the ecliptic at an angle equal to the maximum latitude. Hindu astronomy assumes this motion to be on the ecliptic itself and gives the Moon's longitude, because there is only a maximum difference of 7′. Between the ascending and the descending nodes the orbit is north of the ecliptic and therefore the latitude measured on the great circle perpendicular to the ecliptic and passing through the Moon, is north. Between the descending node and the ascending, the orbit is south and the latitude is south. The distance between the node and the Moon, the latitude and the angle of inclination forming a spherical triangle, we have : sin latitude = sin interval × sin maximum latitude. The maximum being small and the latitude being generally less than this, sin latitude and sin maximum latitude are proportional to the latitude and maximum latitude, and we have the formula, lat = max. lat × sin interval. But the *Pauliśa* takes the latitude proportionate to the interval itself and gives the rule.

We have to consider here whether the author intends that the latitude is to be found in proportion to the actual degrees of the interval or the sine of the interval in degrees. The triangle being spherical, the correct thing would be to use the sine. But we have reason to think that the degrees themselves are intended to be used in the proportion, for if the sine is to be used it must be mentioned. Also, this *Siddhānta* uses only the proportion by degrees in other places also, where proportion by sines alone would be correct, as for e.g. in the solar eclipse, in correcting Rāhu and in calculating *valana*, i.e. transformation of direction (see VI. 2-4, 8). Therefore the original *Pauliśa* itself has instructed proportion by degrees, as being sufficiently accurate, which the author reiterates here. But in computing the parallax (in time) in the case of the solar eclipse the sine is used either by the *Pauliśa* itself, to avoid too much inaccuracy, or by the author VM to save the *Siddhānta* from ridicule. As for TS they say that the author intends here proportion only by sine, that being the proper thing to do.

Another thing should be mentioned here. In using proportion by degrees, the maximum error will be in the neighbourhood of the nodes. With the maximum latitude 280′, the latitude for 13° interval would be 40½ minutes, which would be incompatible with the formula for eclipses (vide VII. 5-6). Therefore it seems that the *Siddhānta*, though knowing that proportion by sine is the correct thing for latitudes, gives proportion by degrees for the sake of ease of computation. Or by taking *liptāśatatrayeṇāśītiṁ* as the correct reading, which would make the maximum 380′, the incompatibility can be avoided. It may be argued that the error in the latitude would be great in the neighbourhood of the maximum. But this is only erring one side while some others err on the other. The mean maximum latitude is 309′. If some like Ptolemy give 240′, which is less by 70′, what is wrong in taking that the *Pauliśa* gives 380′, which is greater by the same amount?

Now for the readings: In the fourth foot of verse 30, *mu* is corrected into *su* because *murāt* is meaningless. In the third foot of the 31st verse two syllables are wanting and *nā* is added for purposes of syntax. For the same reason, *śī-tama-nupā* in the fourth foot is corrected into *śī-tyā-nupā*. The correction of *aśīti* into *saptati* by TS here is unwarranted, because it is not known what it was in the original *Pauliśa*. If this is done in conformity with the *Saura*, why not in conformity with the *Romaka*, which gives 280′, (see VIII. 11), and which is nearer to the *Pauliśa*?

Now follow six verses devoted to criticising the views of the *Romaka*, and an astronomer by name Bhadraviṣṇu, the intention of the author being to create faith in his own work. (This was a custom in those days, vide for instance the *Brāhma-Sphuṭa-Siddhānta, Dūṣaṇādhyāya* and the *Vaṭeśvara Siddhānta, Madhyamā-dhikāra*, Chapter X). In several places of the text the readings are not clear and we cannot be sure of what exactly the author intends to say, though the gist is clear, the matter

not being scientific and amenable to intelligent guess. Still, as there is much to say here too, we are dealing with these, unlike TS who have refrained from doing so.

[भद्रविष्णुमते दोषः]

तिथिनक्षत्रच्छे(द)प्रतिपत्तिर्यदि तथा ततः साधुः |
न तथा च भद्रविष्णोस्तथाऽपि [न] विनिवर्तते लोकः || ३२ ||

Defect in Bhadraviṣṇu

32. If the *tithis* and *nakṣatras* as seen from observation of the sky agree with those computed according to the *Śāstra*, then the *Śāstra* is correct and fit to be accepted. It is not so in the case of Bhadraviṣṇu's work; still people do not turn away from that and follow the correct *Śāstras*.

(This remark about the nature of people is true even today).

For the sake of syntax the long *dā* has been shortened by us. Consistent with the idea intended, the negative particle *na* has been added in the fourth foot.

[पादादित्यमते दोषः]

न युगपदुदयो भानोरस्तमयो वाऽपि भवति सर्वत्र |
कस्मिन् देशेऽस्तमये पादादित्येन (नोक्त)मिदम् || ३३ ||

Defect in Pādāditya

33. Sunrise or sunset is not at the same moment in all places on the earth; (so the place must be mentioned whose sunrise or sunset is taken as the epoch for finding the days and doing the computation). But Pādāditya, who has placed the epoch at sunset, has not mentioned the sunset of which place he refers to. (So his work is faulty.)

There seems to be some error in the last foot and we are not sure whether Pādāditya is a person as we have interpreted, or something else or whether the word is the same at all and not an nth incarnation of the original.

[रोमकमते दोषः]

मार्गा(द)पेतमेतत् काले लघुता न तावदतिदूरे |
'खविषयभूताष्टरसै'रब्दैः पश्याऽस्य विनिपातम् || ३४ ||

32a. A.B.C.D. छेदा
b. A.B1. प्रतिपत्तियदि; B2. प्रतिपतियदि.
B. साधु
c. B. भद्रविष्टमो
d. A.B.C.D. om. [न]

33a. A.B. भानुः
c. D. ०ऽस्तमयः
d. B. पादादिन्येन; D. पादाद्विनेन
A. भुक्तिमिदं; B. भक्तिमिन्दुः; C. भुक्तमिदम्;
D. भुक्तं विदुः

Defect in Romaka

> 34. This *gaṇita* work had deviated from the right path handed down by a hierarchy of good teachers and the day of its exposure is not far distant. Witness its downfall in 68,550 years!

To agree with the fifth case in *mārgāt* we have corrected *upeta* into *apeta*.

It may appear strange that the author calls 68,550 years as a not far distant date. But that depends on the outlook of people, and the Hindu mind, especially the old Hindu mind may consider even this as a comparatively short period.

Or this verse may belong to the criticism of the *Romaka* following immediately, strayed to this place by the mistake of the scribe. In that case the first letter *kha* in *khaviṣayabhūtāṣṭarasaiḥ* should be corrected as *sva* and the expression taken to mean "6855 years, by its own measure", in which case the following is the meaning:-

> "This Romaka has not come down through a hierarchy of good teachers because it follows the Tropical year instead of the traditional sidereal year. It will be exposed in a period of 6855 of its own tropical years, and people will abandon it."

How this will happen and how the number 6855 can be arrived at almost exactly, will be shown in explaining the next verse.

(रौ)मकमहर्गणं (वा) (तद)र्कमिन्दुं च गणयतां ग्रा(ह्यम्)
चैत्रस्य पौर्णमास्यां नवमी नक्षत्रमादित्यम् || ३५ ||

> 35. If we adopt the days from epoch resulting from the tropical year as adopted by the *Romaka* and the Sun or Moon resulting therefrom, we must accept Punarvasu as the *nakṣatra* of the full moon of the month of Caitra, instead of the expected Hasta or Citrā, Punarvasu which is the *nakṣatra* of Caitra-Śukla-navamī.

This connection has been strongly established in people's mind by the observance on Caitra-navami as the birthday of Lord Rāma, hero of the *Rāmāyaṇa*, well known as born in the asterism Punarvasu.

This is how this will happen: The months Caitra, Vaikśākha etc. are so called because the Moon at new moon in these months is in the vicinity of Citrā, Viśākhā etc. Thus, in a given month, the full moon, i.e. the Moon of the 15th *tithi*, is in a given *nakṣatra* or nearby, so that the other *tithis* also are

34a. A.B.C.D.मार्गादुपेत
b. B.न तावैदति दूरो
c. A.षविषय; B.om ख

35a. A.B.C.D.रोमक
a-b. A.B1.ॱणं पादं मर्कॱ; B2.3. C.D.ॱणं पादमर्कॱ A.ॱयतां तां ग्राह्या; B.ॱयतां ग्राह्याः C.ॱयता ग्राह्या; D.ॱयतां ग्राह्य
c. B2.पौर्णिमास्यां
d. D.नवम्यां

connected with particular *nakṣatras*. For e.g. as the Moon of the fifteenth *tithi* in Caitra is near Hasta or Citrā, the Moon of navami, six days before, is near Punarvasu or Puṣya, because the *tithi*, the day and the *nakṣatra*, have approximately the same duration. In the same way, as the Moon of the 15th *tithi* of Śrāvaṇa is near Śravaṇa, the Moon at Śravaṇa Bahula Aṣṭamī, eight days after that, is near Rohiṇī, which is also a thing well known. Now, when the months (synodic) are 'tied' to the *nakṣatras* as mentioned, there will be this conformity. But the months are kept tied to the *nakṣatras* if the solar year is sidereal, and not tropical like that of the *Romaka*, i.e. if the solar year begins as in all other *Siddhāntas* with a fixed point on the ecliptic like the first point of Meṣa, and not the movable vernal equinox, the so called First Point of Aries, as in the *Romaka* or the new Indian *Rashtriya Panchang*. As the difference between the two points (i.e. the *ayanāṃśa)* increases, the above mentioned conformity will gradually decrease and when the *ayanāṃśa* accumulates to 30° the full moon of the first month will fall in the Phalgunis instead of near Citrā and though called Caitra the first month will really be 'Phālguna'. This non-conformity has already happened in the *Rashtriya Panchang*, with the *ayanāṃśa* more than twenty degrees now. If it accumulates to 6 *nakṣatras*, (i.e. 80°) the full moon of the first month, still called Caitra, will be in the *nakṣatras* Punarvasu or Puṣya, though the month will really be Pausha. Thus Punarvasu connected with the Navamī of the real Caitra will occur at the full moon of the so called Caitra of the *Romaka* (or the *Rashtriya Panchang*). The Navamī of the new Caitra, occurring 6 days before the full moon day, will occur in Apabharaṇi, 6 *nakṣatras* earlier. When a situation thus arises contradictory to their belief, people will realise that the sidereal year is the proper thing and discard the *Romaka.*

Incidentally we may mention that the same confusion will arise in following the *Rashtriya Panchang* also. One thing we want to say here. We do not deny that the tropical year best suits civil purposes, but a luni-solar calendar based on the sidereal year also will suit our religious purposes best. Therefore they have to be kept apart. (A civil calendar based on the tropical year, we already have in the Christian Calendar we have been following, which is practically worldwide. As for the defects in it, the 'Calendar Reform' will take care of it, while in making this reform we have taken a step in isolating ourselves.) One thing could have prevented the confusion. If they had adopted the seasonal-month-names like Madhu, Mādhava etc. preserved for us in the Vedas (vide III. 25) instead of trying to fit in the sidereal luni-solar-calendar months, Caitra, Vaiśākha, etc., this confusion would have been avoided and they would not have simply added one more to the one hundred contradictory *Panchangs* already extant.

To continue: We shall compute after how many years the exposure of the *Romaka,* as mentioned by the author, would happen. The *ayanāṃśa* was zero at the author's time, as we have shown on several occasions. We must calculate when it accumulates to 6 *nakṣatras*. The *Siddhāntas* of the author's time use a sidereal year of days, 365-15-31 nearly, and the tropical year of the *Romaka* is days 365-14-48 (See VIII. 1). Therefore, the *Romaka* year begins earlier by 43 *vināḍis*, every year, and this is equivalent to the rate of *ayanāṃśa* per annum, 42″, nearly. If *ayanāṃśa* to become 42″ takes one year, to become 6 *nakṣatras* it will take, $6 \times 800 \times 60$ divided by $42 = 6857$ years nearly. *It is this that is given by the author as 6855 in the previous verse explained.*

कालाऽपेक्षा विधयः श्रौताः स्मार्ताश्च तदपचारेण |
प्रायश्चित्ती भवति द्विजो यतोऽतोऽधिगम्येदम् || ३६ ||

36. All the injunctions of the Vedas and Smṛtis are based on the proper time, and by not performing the rites at those times the performer, especially a twice-born,

acquires sin which is to be expiated. Therefore, a study of this *Romaka* itself is to be expiated.

How is that sin may accrue by not performing a rite at the time enjoined by the *Śāstras*. But by simply studying the *Romaka*, we cannot say one would also perform the rite at the improper time. The *Romaka* may give the time wrongly, but one may study it not for the sake of using its time, but for other purposes, as for instance to understand where it goes wrong, and expose its weakness to others and save them, for which the man who studies even deserves merit. Let us understand that these things, sin and merit, are subtle and cannot be known without a deep study of the *Śāstras*, and if the author steeped in the *Dharma Śāstras* says a thing, let us accept it. The Vedas promise *svarga* not only to the performer of the *yajña* but also to one who knows how to perform it properly. We frequently meet in the Vedas the expression *ya u cainam evam veda.* The *Vedāṅga Jyotiṣa* says that people who know astronomy know as it were the correct performance of the sacrifices themselves, *yo jyotiṣam veda sa veda yajñān* and they go to *svarga* after establishing a long line of progeny in this world.

Now, it stands to reason that if the mere study of a good thing gives merit, the mere study of a bad thing brings sin. It is said that even association with bad characters and sinners bring sin, as also doing sinful things even in dreams. As for the argument that the person even deserves merit for intending to keep off people from the improper times, he does deserve it and will get it. But that does not mean expiation is not called for. Contact with craftsmen may be necessary to keep the temple idols in form, but that does not mean that purificatory ceremonies need not be performed for the idols on that account. We can say this much that in these cases the expiation is light, like the utterances of the Lord's Name, like 'Kṛṣṇa Kṛṣṇa, Śiva Śiva! We should also take into consideration the spirit if the times in which these statements were made.

स्फुटगणितविदिह लब्धा धर्माऽर्थयशांसि दिनकरादीनाम् |
(कुकरणकारस्सत्यं सहते नरके कृताऽऽवासाः || ३७ ||)

37. The person having correct knowledge of the Sun, Moon, etc. gets *Dharma*, which will take care of his future world, *Artha* which will ensure his prosperity in this world and fame, which will perpetuate his memory. But the bad astronomer who misleads people by his writings will certainly have to go to hell and dwell there.

36a. A. विघय
b. B. श्रौता स्मा°
c. B1.2. प्रायश्चिती. A1. भवती

37. In A and B, स्फुट etc. occurs as the second half of the verse. It is put here as the first half to suit the sense.
a. D. लब्ध्वा

c-d. A. कुकरणविदो द्विन्यो ये कथयन्त्यस्फुटं कुकरणकारः (A2. करः)
B. अकरणविदो द्वित्यो ये कथयसत्यं अकरणकरः सहते नरके कृतावासाः ।
C. कुकरणविदोद्विन्यो ये कथयन्त्यस्फुटं कुकरणकरः सहते नूनं नरके कृतवासाः ।
D. कुकरणविदो द्विजा ये कथयन्त्यस्फुट [म] सत्यं [स गणितम्] ।
कुकरणकारसहि [ताच्च] ते क्षणं नरके कृतवासाः ||

It must be noted here that when even the person with correct knowledge gets so much, the writer will get more. It must also be noted that only the writer of bad astronomy goes to hell, not the reader, whose sin is small.

In this verse there is a jumbling of words and phrases and induction into the text extraneous words intended as commentary. The words, *sphuṭagaṇitavid* etc. seem to be the first half of the verse because in the first foot there are twelve and in the second eighteen syllables. Therefore what comes before that is the second half. In that, there are may syllables more than the required twenty-seven. Selecting the required words alone, we have reconstructed the third and fourth foot.

For the observations of K S. Shukla on 32-37 *vis-a-vis* NP, see his paper 'The *PS* of VM (1)', *JIHS* 9 (1974) 62-76.

[इति पञ्चसिद्धान्तिकायां वराहमिहिरविरचितायां
पौलिशसिद्धान्तो नाम तृतीयोऽध्यायः ||][1]

1. A.B. पौलिशसिद्धान्तः; C.D. इति पौलिशसिद्धान्तः ||

Thus ends Chapter Three entitled 'Pauliśa-Siddhānta: Planetary Computations etc.' in the Pañcasiddhāntikā composed by Varāhamihira

Chapter Four

THREE PROBLEMS — TIME, PLACE AND DIRECTION

४. चतुर्थोऽध्यायः
त्रिप्रश्नाधिकारः

Introductory

Problems on Time, Place and Direction, involving spherical trigonometry, are dealt with in this chapter. The first fifteen verses are devoted to the construction of a table of sines. As this kind of matter does not involve constants specific to any *siddhānta* and is commonly found in all *siddhāntas*, we cannot say which *Siddhānta* this belongs to, *Pauliśa* or *Saura*, the only two *siddhāntas* meant to be expounded in detail by the author. Probably it is the author's own, meant for both, or taken from both. Two things point to this conclusion: In the part of the work dealing with the Saura, *viz.*, chs. IX, X, XI, XIII, XIV, XV, XVI, and XVII, no space is given to the sine tables, though required, and to the problems dealt with here, and therefore if these are not meant for *Saura*, it would be imperfect though almost full. On the other hand, certain redundant and crude rules point to this chapter's connection with the *Pauliśa*, as also its position in the chapter distribution in the *PS* text.

[ज्यानयनम्]

षष्टिशतत्रयपरिधेर्वर्गदशांशात् पदं स विष्कम्भः ।
तदिहां(शच)तुष्कं संप्रकल्प्य रा(श्य)ष्टभागज्या ॥ १ ॥

Table of R Sines

1. Take the circumference as measured in 360 units, square it, take the tenth part of the square, and find its square root. The result is the diameter of the circle in the units taken. We assume the diameter to be 4°, (*i.e.*, 240′) and hereunder give the tabular sines of angles for 3° 45′ interval.

The rule is: diameter = $\sqrt{\text{circumference}^2/10}$. It comes to this: $d = c/\sqrt{10}$. The formula, $d = c/\pi$ is well known, and the author has taken $\sqrt{10}$ as an approximation for π which is incommensurable and usually represented by the approximate values, 22/7, 355/133, 3.1416 etc. The *Sūrya Siddhānta* too gives $\sqrt{10}$ as the value of π in its instruction to find the circumference of the earth from its diameter (I.59.): "The earth's diameter is 1600 *yojanas*. Square this, multiply by 10, and find the square root. This is the earth's circumference." By thus taking $\sqrt{10}$ for π, an error of about 0.0067% results, and for a circumference of 21,600′, we get the radius 3415′, instead of the well-known 3438′. But it must be mentioned here that this error does not affect the computation of the sines

1a-b. A.B. परिधे वर्ग
b. A. विष्कुम्भः
c. A.B. तदिहांशाश्चतुष्कं (B. ०ष्क)
d. A. संप्रकल्प्य; B. प्रकल्प्य. A.B. राश्याष्ट०

mentioned in the succeeding verses, because it can be shown that the author derives the sines from a correct formula, (not dependent on this wrong ratio of the diameter to the circumference), based on 120′ as the radius of the circle. If he had depended on the wrong value, the first tabular sine, *i.e.* sin 3° 45′ would be 7′ 54″, (being the 96th part of the circumference, where the sine is indistinguishable from the arc), and not the correct 7′ 51″ as given by the author.

Taking the diameter as 4°, and thereby the maximum sine (i.e. the radius) as 120′, is arbitrary. In general, the *Siddhāntas* give the maximum sine, 3438′, as arrived at from taking the circumference as 360° or 21600′. The *Vākyakaraṇa* makes it 43°. In actual work, the sines enter only as a ratio to the maximum sine, and therefore no harm, will result by taking these different maximum sines.

TS and NP have not understood the meaning of the second half of the verse, and mis-interpret *aṃśacatuṣkam* as quadrant.

व्यासार्ध[स्य] कृतिर्ध्रुवसंज्ञिका कृतांशस्ततः स मेषस्य |
ध्रुवकरणी मेषोना द्वयोस्तु राश्योः पदं ज्याः स्युः || २ ||

2. The square of the radius, (i.e. 14,400), is called *dhruva (karaṇī)*, (literally, 'Fixed Irrational'). The fourth part of it, (i.e. 3600), is the *karaṇī* (Irrational) related to the first sign, (or 30°). *Dhruvakaraṇī minus* the *karaṇī* of Meṣa, (i.e. 14,400 − 3600 = 10,800), is the *karaṇī* of two signs, (or 60°). The square root of a *karaṇī* is the tabular sine.

Being square of tabular sines given in minutes, the *karaṇīs* are squares of minutes, which is their peculiarity as given by the author, though this is not mentioned explicitly. The other well-known characteristic of a *karaṇī*, viz. irrationality, is found in all *karaṇīs* except 14,400 and 3600, though the author calls these also *karaṇīs* in a general way.

In modern terminology the word sine used in connection with the angle is defined thus:

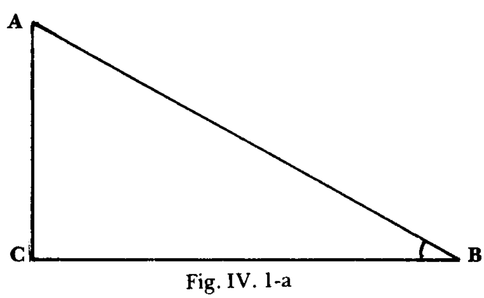


Fig. IV. 1-a

In the right angled triangle, (fig. 1-a), sine ∠ B = AC/AB, or sine ∠ A = BC/AB, i.e. as the ratio of the opposite side to the hypotenuse. In tabulating the sines, the hypotenuse is taken as unity, and the ratio expressed as a decimal fraction.

2a. A.B.कृते ध्रुव°; C.D.कृतिध्रुव°
b. A.B.°ज्ञिता. A.B.कृतांशाःस्ततः. A.B.सशेषस्य
c. B1.3.येयोना; B3.येषोना
d. A.दयोस्तु; B.दयो सु

The ancients however expressed the sines in minutes-length or, more accurately, in minutes and seconds-lengths, the maximum sine called *Trijyā* (meaning 'the sine of three signs', i.e. 90°), occurring separately in the work to make up the ratio. This is the way in which they conceived the sine (meaning 'bow-string' from its Sanskrit equivalent *śiñjinī*, synonymous with *jyā*).

In *Fig. 1-b.* A_3 E F_3 D is the circumference of the circle, centre B. A part of the circumference like ADF, A_1D F_1, etc. is called *dhanus* (literally, 'bow') or arc.

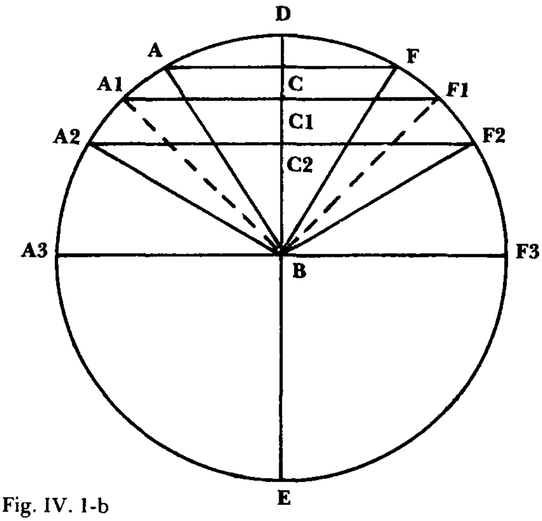


Fig. IV. 1-b

The straight lines ACF, $A_1C_1F_1$, etc. forming the 'bow-strings' of the respective 'bows' are the *jyās* or full sines. But in actual practice, the halves of the full sines AC, A_1C_1, etc. above are used with the name of 'sines', with respect to the half-bows or arcs, AD, A_1D_1, etc. Because the arcs AD etc. are as the angles ABD etc., the sines AC etc. are spoken of with respect to the angles ABD (= ABC) etc. also. Thus, AC is the sine of $\angle$ ABD or arc AD, A_1C_1 is the sine of $\angle$ A_1BD or arc A_1D_1 and so on. It is this connection of the sine with the arc that has given it the nature of a length, which is expressed in minutes and seconds on account of the connection of the arc with the angle at the centre. It may be mentioned here that CD, C_1D, C_2D etc., appearing like the arrows on the respective bow-strings, are called *śara* (meaning 'arrow').

If A_3BD is a right angle, i.e. three signs, then, obviously, A_3B is the sign of this angle, i.e. it is the sine of three signs, and therefore called *trijyā*. Its length is clearly half the diameter A_3BF_3, *i.e.* the radius, equal to 120′.

Now, let the angle ABD be equal to one sign, *i.e.* 30°. ABD = DBF = 30°. ∴ $\angle$ ABF = 60°. AB = BF, being radii. ∴ $\angle$ BAF = $\angle$ BFA = 60°. Thus ABF is an equilateral triangle, and AF = AB = 120′. ∴ AC = AF/2 = 60′. Thus sine 30° = 60′. Its *karaṇī* is its square, viz. $(60')^2 = 3600$, the *karaṇī* of Meṣa as mentioned by the text.

Then, let $\angle$ A_2BD be equal two signs, or 60°. A_2BD = DBF_2 = 60°. ∴ C_2 is a right angle. So the *karaṇī* of 2 signs = $A_2C_2^2 = A_2B^2 - BC_2^2 = A_2B^2 - AC^2$, (∵ $\triangle$ $A_2B\,C_2 \equiv \triangle$ BAC), = $120^2 - 60^2$ = 10,800, A_2B being the radius. This also agrees with what the text says. (The square root of 10800 minutes, i.e. 103′ 55″, is the sine of 2 signs, which agrees with the value given in the table.)

Incidentally, we shall derive the *karaṇī* and sine of one and a half signs, i.e. 45°, mentioned in verse 4. Let A_1BD be equal to 45°. $\angle A_1 = 45°$, and $\angle C$ is a right angle. ∴ $A_1C = C_1B$. But, $A_1B^2 = A_1C_1^2 + C_1B^2 = 2A_1C_1^2$. ∴ $A_1C_1^2 = 120^2/2 = 14400/2 = 7200$ = the *karaṇī* of one and a half signs as mentioned in the text. Its root, 84′51″, is sine 45°, agreeing with what is given in the tables.

शेषेष्विष्टेषु धनु-र्द्विगु(णं) पदात् प्रोज्झ्य शेषगुणहीना [त्] ।
[व्यासस्याऽर्धाद्वर्गं] द्विगुणकरण्यां समायोज्यम् ॥ ३ ॥
तत्पादोऽभिमता [स्याद्] ध्रुवा तदूनाऽवशेषपिण्डस्य ।
ध्रुवकरणीदलमध्यर्धसंज्ञमन्योऽत्र विधिरुक्तः ॥ ४ ॥
इष्टांशद्विगुणोनत्रिभज्ययोना त्रयस्य चापज्या ।
षष्टिगुणा सा करणी तया ध्रुवोनाऽवशेषस्य ॥५ ॥

3-5. The other tabular sines, (i.e. sine 3° 45′, sin 7° 30′ etc. other than the four mentioned of the total 24) are formed successively in the following manner: Let the angle or arc for which the sine is required be $\emptyset$.

I. $\sin^2\emptyset = \frac{1}{4}[\sin^2 2\emptyset + \{120 - \sin(90° - 2\emptyset)\}^2]$

II. $\sin^2\emptyset = 60 \times \{120' - \sin(90° - 2\emptyset)\}$, where the sines are in minutes etc. Of the 24 sines, the *karaṇī* of the nth sine = 14400 − the *karaṇī* of the (24 − n)th sine. 7200 is the *karaṇī* of one and a half signs, i.e. 45°.

Thus, as *karaṇīs* 8, 12, and 16 are known, those of their halves etc. and (24 − halves) etc. can be found successively. Thus all the sines from 1 to 24 can be found. Of the two formulae, the first is suited to geometrical representation, and the second to computation.

Example 1. Given the 8th karaṇī (i.e. of 30°) 3600 and its sine 60′, the 16th karaṇī (i.e. of 60°) 10800, and its sine 103′ 55″.33, find the 4th and 20th karaṇīs and sines, using each of the two formulae.

The desired sine is the 4th, i.e. of 4 × 3° 45′ = 15°. $2\emptyset$ = 30°, 90° − $2\emptyset$ = 60°.

3a. A. धनुद्वि. A.B.C.D. ०गुणपदा०
b. A. पदायोज्य; B. पदाज्योज्य; C.D. पदायोग०
A.C.D. गुणहीना; B. गुणाहीना
c. A.B. तृन्यासपादार्द्धाद्धर्ग; (B. om तृ; B2. ०र्गी);
C.D. [त्रिज्या तदर्धवर्गौ] द्वि
d. A. कारथो; B. कारयो
A. समायोज्यं; B. समाप्रोज्यन्त;
C. द्विगुणज्यार्धस्य संयोज्यः; D. द्विगुण [र्ध] करणी समायोज्यः

4a. A. तपदो; B. पदो; C.D. त [स्य] पदो.
A.B.C.D. ०भिमतज्या
b. A. तदुना. B. ०विशेषे
d. A. र्द्धसंज्ञा; B1.2. र्द्धसंज्ञां; B3. र्द्ध संज्ञा
C.D. संज्ञकोऽन्योऽत्र. A. विधिनुक्तः

5a. A.C. इच्छांशद्विगुणेन (C. ०णोन)
b. B3. त्रयंस्य A.B. वायज्या
c. A. स कारणी; B. स करणी
d. B. वपा. A.B. ०नामशेषस्य

I. The 4th *karaṇī* = $\frac{1}{4}[\sin^2 30° + (120 - \sin 60°)^2]$
$= \frac{1}{4}[60^2 + (120 - 103' 55''.33)^2]$
$= \frac{1}{4}[3600 + (16' 4''.67)^2]$
$= \frac{1}{4}(3600 + 258\ 97/144)$
$= \frac{1}{4}(3858\ 97/144) = 964\ 385/576$

$\therefore$ the fourth sine, i.e. sine 15° = $\sqrt{964\ 385/576} = 31' 4''$.

II. The 4th *karaṇī* = 60 (120 − sin 60°)
$= 60' (120' - 103' 55''.33)$
$= 60' \times 16' 4''.67 = 964\ 385/576$

From this, sin 15° = $\sqrt{964\ 385/576}$ as before = 31′ 4″.

We shall prove the first formula geometrically, and derive the second from the first.

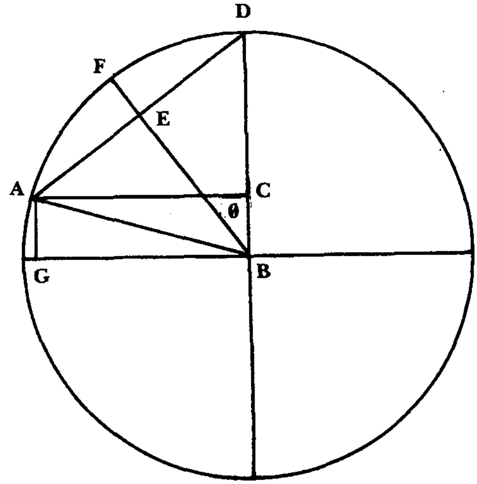


Fig. IV. 2

In Fig. 2, FBD = θ, and DF is its arc of which the sine wanted is DE.

DE^2 = the wanted *karaṇī* (i.e. $\text{sine}^2\ \theta$). DFA = 2DF.
$\therefore DE = \frac{1}{2}DA. \therefore \sin^2\theta = DE^2 = \frac{1}{4}DA^2 = \frac{1}{4}(AC^2 + CD^2)$.
Now, $\because$ AC = sine 2 arc FD = sin 2θ, $AC^2 = \sin^2 2\theta$; and $\because CD^2 = (BD - BC)^2 = (BD - AG)^2 = [120' - \sin(90° - 2\theta)]^2$, $\sin^2\theta = \frac{1}{4}(AC^2 + CD^2)$
$= \frac{1}{4}[\sin^2 2\theta + \{120' - \sin(90° - 2\theta)\}^2]$

From this, $\sin\theta = \sqrt{\sin^2\theta}$.

From I, we can derive II thus:
$\frac{1}{4}[\sin^2 2\theta + \{120' - \sin(90° - 2\theta)\}^2]$
$= \frac{1}{4}\{\sin^2 2\theta + 120^2 + \sin^2(90° - 2\theta) - 2 \times 120 \times \sin(90° - 2\theta)\}$
$= \frac{1}{4}\{120^2 + 120^2 - 2 \times 120 \times \sin(90° - 2\theta)\}$

($\because \sin^2 2\theta + \sin^2(90° - 2\theta) = \sin^2 2\theta + \text{Cos}^2 2\theta = \text{radius}^2$)
$= \frac{2 \times 120'}{4}\{120' - \sin(90° - 2\theta)\}$
$= 60'\{120' - \sin(90° - 2\theta)\}$

Now, of TS, Thibaut alone proves the formula, while Sud. Dvivedi uses it. The form of the first formula given by them differs from that given by us, and is as follows:-

$\sin^2\theta = (\frac{1}{2}\sin^2 2\theta) + [\frac{1}{2}\{120' - \sin(90° - 2\theta)\}^2]$

Though their formula is correct, it entails more work, and to give the formula in this form they have made many unwarranted changes in the already correct readings. We have made only one correction, and that grammatical, for the sake of syntax, viz. *dhanurdviguṇapadāt* into *dhanurdviguṇam padāt*, which entails the occurrence of an extra syllable, which can be explained, as before, by rules of prosody. Or, let the reading be *śeṣe tviṣṭe dhanurdvi-guṇam padāt projjhya* etc.

Now follow six verses giving the sines, computed by the author himself.

शेषज्याः 'स्वरतिथयो' 'गुण-शिव-घृति'भिश्च 'विंशतिः' सहिता |
'पञ्चनरकं' 'शतार्धं त्रिसमेतं' 'षष्टि'रिति लिप्ता || ६ ||
सैकाऽजे पञ्चाशत्' 'पञ्चाष्टकं' 'पञ्चवर्गवेदा' श्च |
'त्रिंशच्चतुर्भिरधिका' 'षट्पञ्चशच्छराः' शून्यम्' || ७ ||

6-7. The other sines are the following: In the first sign, the minutes parts are successively 7, 15, 20 + 3, 20 + 11, 20 + 18, 5 × 9, 50 + 3, and 60. The seconds, respectively, are: 50 + 1, 5 × 8, 25, 4, 30 + 4, 56, 5 and 0.

Thus we have for the first sign –

Sine no.	1	2	3	4	5	6	7	8
Arc or angle	3° 45′	7° 30′	11° 15′	15° 0′	18° 15′	22° 30′	26° 15′	30° 0′
Sine	7′ 51″	15′ 40″	23′ 25″	31′ 4″	38′ 34″	45′ 56″	53′ 5″	60′ 0″

'षट्' 'त्रयोदशै' '(कोना) विंशति स्' 'त्र्यष्टकान्य'त'स्त्रिंशत्' |
युक्ता'म्बर-पञ्चनवा(तिज)गतिभि'र्लिप्तिका वृषभे || ८ ||
'चत्वारिंशद्रामा मुनयोऽर्धशतं च सैक(मतिजगती)' |
'द्वादश' 'षष्टि(हीं)ना मनुभिर्विषयै'र्वृषे विकलाः || ९ ||

8-9. Of the sines in the second sign, the minutes parts taking the increments in the current sign alone, are, successively, 6, 13, 20 − 1, 3 × 8, 30 + 0, 30 + 5, 30 + 9, and 30 + 13. The respective seconds are: 40, 3, 7, 50 + 1, 13, 12, 60 − 14, and 60 − 5.

6a. A.B. शेषज्या; C.D. मेषज्याः. B. स्वस्वर
b. A. ०भिश्चविंशतिः; B. ०भिश्चाविंतिः. B. सहिताः
c. A.B. शतार्द्धं
7a. B. सैकाये
b. B.C.D. पञ्चाष्टकपञ्च
c. B. चतुर्भिरयेका
d. A. षट्वञ्चाशछराः

8a. B. षट्त्रयो. A.B. ०दशौकात्र विं०; C.D. दशैकोनविं०
b. B. विंशति. C. त्र्यष्टकोऽन्यतः. A. त्रिशतृ
c. A. शुक्लांबर
c-d. A.B. नवांद्रि (B. द्वि) जागतिभिः (A. om भिः)०
C. नवाग्निहिमगुभिः; D. नवत्रि [ज] गतिभिः
d. B. लिप्ताका (B3. प्रि)
9a. B2. चचारि. B1.2. ०द्रमा
b. A1. मुनयोर्द्ध. A.B. सैकमिति गति; C. सैकमतिजगती;
D. सैकं त्रि [ज] गतिः
c. A.B.C. षष्टिहीना; C. द्विरति द्वादशषष्टि
d. A.B. मनुभि; C. मनुसागरैः

Adding the minutes and seconds, and 60′ for the end of the first sign, the sines are:-

Sine no.	9	10	11	12	13	14	15	16
Arc or angle	33°45′	37°30′	41°15′	45°0′	48°45′	52°30′	56°15′	60°0′
Sine	66′40″	73′3″	79′7″	84′51″	90′13″	95′12″	99′46″	103′55″

'(गुण-रस-नवका)' 'दशभि-र्द्वि-त्रि-भूत-भूत-(रस'-युक्ताः) |
ज्यापिण्डा पि(ण्डा) ये द्वितीयराशा(व)तो विकलाः || १० |
'धृति-गुण-धृति'-परिहीना 'षष्टिः' 'शून्यं' 'शतार्धमनलोनम्'
'वेदा' 'व्येकार्धशतं' 'पञ्चे'ति, तदन्तरज्याः स्युः || ११ ||

10-11. Of the sine increments gone in the third sign, above the second, the minutes are: 3, 6, 9, 10 + 2, 10 + 3, 10 + 5, 10 +5, and 10 + 6. The respective seconds are: 60 − 18, 60 − 3, 60 − 18, 0, 50 − 3, 4, 50 − 1, and 5. Next follow the sine intervals.

Adding the given minutes and seconds to 103′ 55″ the sine of 2 signs, we have:

Sine no.	17	18	19	20	21	•22	23	24
Arc or angle	63°45′	67°30′	71°15′	75°0′	78°45′	82°30′	86°15′	90°0′
Sine	107′37″	110′52″	113′37″	115′55″	117′42″	118′59″	119′44″	120′0″

In one or two places we have corrected the corrupt readings, having in view what exactly should be the number as found by computation. But TS have made corrections that give wrong values for the already correct values. For e.g. the fourteenth sine, 95′ 12″ given by the text is correct, while they make it 95′ 13″ by an unwarranted change, giving it an unlikely form. The 16th sine, 103′ 55″ given by the text is correct, but they make it 103′ 56″ so that in every sine of the third sign, 17-24,

10a. A.B.C.D.गुणनवरसकादश॰
a-b. A.B.॰दशभिश्चद्वि; C.॰दशविश्चेद्विस्त्रि॰. D.॰दशविश्वा द्विस्त्रि॰
b. A.B. भूतभूतभुकृत्यंतरसा; C.D. भूतभूपान्तरजाः |
c. D.ज्यालिप्ताः. A.B.D.पिण्डोऽयं; C.पिण्डाद्या
d. B.राशायतो; C.राश्यन्ततो
11b. A.षष्टिशून्यं. B.मनलोन |
d. B1.2.पञ्चेनि; B3.पचेनि. A.ज्या स्युः

there is one second more. By this mistake the 24th, i.e. the radius, has become 120′ 1″, and even this obvious mistake they have failed to note.

The promised sine-intervals are here given:

मुनयो'ऽजे व्येकान्ते 'रसत्रयं' 'पञ्च(कौ)' 'कृता' (श्च) गवि |
'शिस्वि-पक्षचन्द्र-शून्याः' द्विर्द्विर्मिथुने कला ज्या[नाम्] ||१२ ||
मेषे विकलार्धशतं सैकं 'व्येकेन्द्रि(ये)-श्वरं त्रिंशत् |
(द्वा)विंशतिस्त्रिवर्गः ---------------------- || १३ ||
-- |
------ 'खगुणकृतार्णवयमनवकसमुद्रशिखिवर्गैः || १४ ||

12. Of the intervals the minute parts are, in the first sign, 7, 7, 7, 7, 7, 7, 7, 6; in the second sign: 6, 6, 6, 5, 5, 4, 4, 4; and in the third sign, 3, 3, 2, 2, 1, 1, 0, 0.

13-14. The seconds in the first sign are, 50 + 1, 50 − 1, 50 − 5, 50 − 11, 30, 22, 9, (and here is a break resulting in the loss of the 4th foot of the 13th verse and the first two feet with 4 *mātrās* of the 3rd foot of the 14th verse. From the values of the sines we can compute that the seconds in the 8th interval must be 55, which must have been given in the missing part. By examining the remaining part we can construct the meaning of this verse thus). The seconds of the intervals in the second sign are, respectively 10 × (4, 2, 0, 4, 2, 5, 3, 0) + (0, 3, 4, 4, 2, 9, 4, 9), added each to each.

TS have not been able to see that in what is left of the 14th verse, the digits in the unit places of the eight numbers giving the seconds of the intervals of the second sign are given. This is because they have made mistakes in the 14th and 16th sines resulting in an error of + 1″ in the 14th interval, − 1″ in the 15th and + 1″ again in the 16th. This has prevented them from finding the correct values by comparison, so that they make many changes in the readings here, saying that the text is very corrupt, here. It may be seen that not a single word is wrong here.

12a. A. न्मुनयोज्ये; B. गुनयोज्ये
b. A. त्रयं को; B. त्रयपञ्चको;. C. त्रयं (त्रिः) शशः
A. कृताच्चे गवि; B. कृता-गेवि; C. कृताब्धी गवि;
D. कृताग्निऽवि
c. A. शिखिपकृत चन्द्रः; B. शिपिपक्ष
d. C. द्वौद्विमिथुने. A-B. ज्या |; C. ज्यार्द्धे; D. ज्या[सु]
13a. A. विकलार्द्धशत॰
b. B1. सैकां; B2. सैव्यं;
A1.B1. ॰न्द्रिय स्वरं
c. A1.B2. द्विविंशति
13d. A.B. Unindicated gap of 13d. upto खगुण of 14c.

to 14c. D suggests for 13d [पञ्चाशच्च विषयसंयुक्तम्]
C. indicates the gap by dots as done by us. D suggests for 14:
ख[समुद्र] गुण [द्विकृताः] ....
कृतार्णव [द्वि] यमनवे [न्द्रि] यसमुद्रशिखिस्वर्गे[शाः] ||

d. A. समुद्रा
B1.2. वर्गे; B2. वर्गै
C. खगुणकृतार्णवयमनवसकसमुद्रा शिखिवर्गैः (?) ||

'मनुविषयतिथिरसाः' स्युस्त्रिगुणाः पञ्चाष्टकं 'स्वरोपेतम्' |
सप्तदशनवपञ्चकं षोडश चेति क्रमान्मिथुने || १५ ||

15. The seconds of the intervals in the third sign, are, 3 × 14, 3 × 5, 3 × 15, 3 × 6, 5 × 8 + 7, 17, 9 × 5 and 16.

The intervals can be got by deducting the previous sines from the succeeding ones, and compared with the author's concern for correctness, they are correct. It is to be noted that the intervals of TS also come correct in the third sign, because there is a uniform error of 1″ in all sines. The intervals are as tabulated:

No.	0	1	2	3	4	5	6	7
Int.		7′ 51″	7′ 49″	7′ 45″	7′ 39″	7′ 30″	7′ 22″	7′ 9″
No.	8	9	10	11	12	13	14	15
Int.	6′ 55″	6′ 40″	6′ 23″	6′ 4″	5′ 44″	5′ 22″	4′ 59″	4′ 34″
No.	16	17	18	19	20	21	22	23
Int.	4′ 9″	3′ 42″	3′ 15″	2′ 45″	2′ 18″	1′ 47″	1′ 17″	0′ 45″
No. 24 Int. 0′ 16″								

These intervals are useful for interpolation. The method of interpolation has not been given by the author, as being obvious. The intervals being increments in the series for successive increments in the arcs (or angles) of 3° 45′, we can find the value for what is left over after taking the tabular value, by proportion, and adding it to the tabular value find the value wanted, whether it is arc for sine, or sine for arc.

Further, the author has given the sines of arcs upto 3 signs, as usually given in tables. But the method to compute the sines of arcs greater than three signs, has not been mentioned by him.

We shall find a method. The circle is divided into four quadrants (Fig. 3), AOB, BOC, COD and DOA, each quadrant being three signs. Arcs AE = HC = CK = GA, from which their sines, EF = HJ = JK = GF. But, since the sines increase in the first quadrant from O at A to BO (= 120′) and then decrease in the second quadrant from 120′ to O at C and again increase in the third quadrant to DO (= 120′) and then again decrease in the fourth quadrant to O at A, sine AE = sine AH = sine

15a. B. मुनि विषय. A. om स्यु
b. B. त्रिगुणा पञ्चाष्टक
c. B. ०दशन्वपञ्चकके
d. A. ०मिने (i.e. on थु)

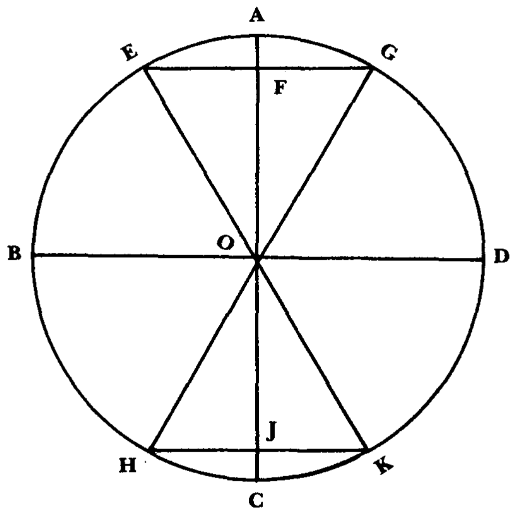


Fig. IV. 3

AK = sine AG (neglecting the first sign) because, EF, HJ, JK, GF, are all equal, as already mentioned. Therefore, for an arc or angle in the second quadrant, (3 to 6 signs), deduct it from six signs and get the sine of the remainder. For that in the third quadrant, (6 to 9 signs), deduct six signs and find the sine of the remainder. For that in the fourth quadrant, deduct it from twelve signs and find the sine of the remainder.

Example 2 (a). Find the sine of the arc or angle equal to 4 signs.

It is in the second quadrant. Therefore, sine 4 signs = sine 6 signs − 4 signs = sine 2 signs = 103′ 55″.

Example 2 (b). Find the sine of signs 7-11-15.

This is in the third quadrant. Therefore sine of sign 7-11-15 = sine (7-11-15 − 6-0-0) = sine 1-11-15 = 79′ 7″.

Example 2 (c). Find the sine of signs 9-15-0.

This is in the 4th quadrant. Therefore sine of signs 9-15-0 = sine (12 signs − sign 9-15-0) = sine 2-15-0 = 115′ 55″.

Declination

From here to the end of the chapter, problems based on the solution of spherical triangles are dealt with, being problems involving position, time and direction. As a preliminary, the declination of the Sun and the Moon are required, which are given first.

Stellar sphere (Bhagola)

The ancient astronomers speak of three spheres, the Terrestrial sphere or Earth sphere on which we live, the Stellar sphere or the Sphere of the stars, and the Sky sphere or the Sphere of the sky. We shall describe the terrestrial sphere in connection with the Sàura chap. XIII-XV. Of the other two, we shall now describe the stellar sphere, a knowledge of which is immediately required. It is the apparent sphere on which the stars appear to be fixed, and form a frame of reference for

the motion of bodies like the Sun, Moon, planets etc. Actually the stars are at widely different distances from us and are moving in various directions at speeds of several miles per hour. But with all this they appear to be, and can be represented, as being fixed on a sphere, because of their enormous distances from us, so much so that we are practically viewing the same sphere as people several generations ago did. But the ancients believed that the stars were luminous bodies fixed on the under-surface of a sphere of radius only sixty times that of the orbit of the Sun (actually the earth) round the earth, with the centre of the sphere at the earth's centre. This sphere *seems* to be rotating about once a day, by the actual rotation of the earth, about once a day.

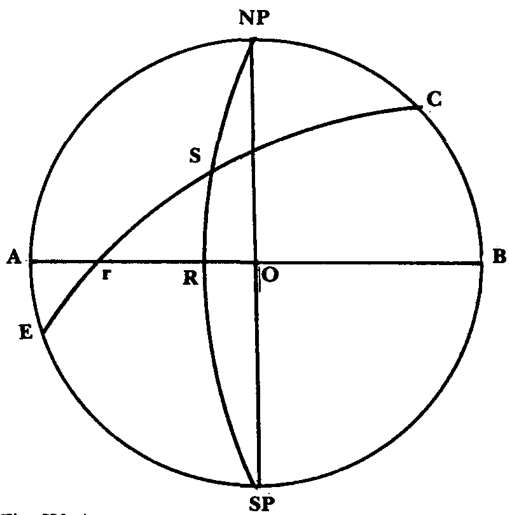


Fig. IV. 4

On this sphere (Fig. 4) there is an important great-circle called the ecliptic (*Krānti-vṛtta*) (EC), marked by the twenty-seven asterisms, Aśvinī etc., on which the Sun (S) moves, (actually appears to move on account of the motion of the earth), completing a revolution once a year. The Moon and the planets move in orbits inclined to the ecliptic at small angles. Their longitudes are reckoned along the ecliptic from a fixed point called the first point of Meṣa or Aśvinī. Latitudes are measured on secondaries to the great circle, meeting at a point called the pole of the ecliptic (*Kadamba*). Another great circle called the Celestial Equator (AOB) cuts the ecliptic at r, called the First point of Aries or Vernal Equinox point, which, instead of being fixed, has a slow westward motion on the ecliptic. At the period of the authors of the first *Siddhāntas*, this point coincided with the first point of Meṣa, this being the reason why that particular point was taken by them for reckoning from. The angle between the two great circles (SrR) is called the Obliquity of the ecliptic. It was about 24° at the time of Varāhamihira, and now it is about 23° 27′. The declination (SR,) (*Krānti*) of a body like the Sun, is measured along the secondary passing through the body, (NPSRSP,) called the Declination circle, all the secondaries meeting at the celestial poles, the poles of the stellar sphere, (SPNP), on the axis joining which the sphere apparently rotates.

The declination is found by solving the spherical right angled triangle SrR. Spherical triangles were in general solved by the Hindu astronomers using the properties of plane right angled triangles formed by the sections of the sphere along the great circle arcs forming the spherical triangle (The

Greeks solved them by an extension of Manelau's Theorem to figures on the sphere.) We shall content ourselves with giving the formulae for solution and refer to them whenever necessary by way of proof.

Let ABC (fig. 5) be a spherical triangle, right angled at C, and R the radius of the sphere.

I. Cos AB = Cos AC × Cos BC ÷ R
II. sin BC = sin AB × sin A ÷ R
III. Cos A = R × Cos AB. sin AC/sin AB. Cos AC
IV. Cos A = Cos BC × sin B ÷ R
V. Cos AB = R. Cos A × Cos B/(sin A ×sin B)

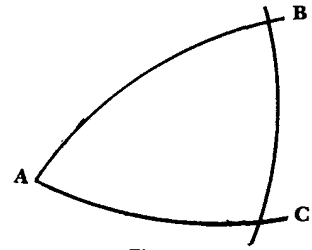


Fig. IV. 5

These, together with the general identities, cosθ = sin (90° − θ), $\sin^2\theta + \cos^2\theta = 1$, will suffice for explaining the formulae occurring in the text.

[रविचन्द्रयोः क्रान्तिः]

जीवाऽ'धयर्धशतां' (शघ्नै)काषष्टि(र्दि)नेशकाष्ठा (ज्या) |
चन्द्रस्य सविक्षेपस्तदपक्र(मो) राशिपादे(भ्यः) || १६ ||

Declination of the Sun and the Moon

16. The sine of Sun's declination is found by multiplying the sine of its longitude by 61 and dividing by 150. Its arc is the declination. The declination of the Moon found thus is the mean declination. Its true declination is the mean declination *plus* latitude. The intervals of declinations for intervals of quarter signs are given (in the next two verses, 17-18).

This is the formula: sin dec. = sin sāyana long. × 61/150. From this the arc forming the declination is found by using the tables, and then the true declination of the Moon, using this. It must be noted that when the longitude reckoned from r (i.e. sāyana long.) is within 6 signs, the declination is North, and when more than 6 signs it is South. In the case of the Moon, if the declination and the latitude are of the same direction they should be added to get the true declination. If they are of different directions, their difference is the true declination, its direction being that of the greater. The author has not mentioned this because it is obvious.

Example 3 (a). Find the maximum declination of the Sun.

Obviously, the maximum sine of the Sun's longitude (i.e. when the Sun is 3 signs or 9 signs) will give the maximum declination. It is therefore given by sin dec. = 120′ × 61 ÷ 150 =48′ 48″. Its arc, 24° is the maximum declination.

16a. A. जीवाध्यार्द्ध॰; B. जीवा व्या-र्द्ध; C. जीवाब्ध्यर्द्ध; D. जीवाव्यध्यर्ध. B. सिताशा; A.C.D. शतांशाः D. [साङ्कलिप्ता]. A.B. काष्टान्तः; C. काष्ठान्तः; D. काष्ठान्तः

b. A. सैकाःषष्टि; B. सैका षष्ठि; C. सैका षष्टि;

d. A.B.C.D. तदपक्रम. A.C. ॰पादेन्यः

Example 3 (b). Sāyana Sun is rāśi 4-7-30. Find its declination.

Sin $4^r 7° 30'$ = Sin (6^r-0-0 − 4^r-7-30) = sin 1^r-22-30 = 95′ 12″.

Sin Declination = 95′ 12″ × (60 + 1) ÷ 150 = 95′ 12″ × (2/5 + 2/5 × 60) = 38′ 5″ + 38″ = 38′ 43″.

Its arc, 18° 50′, is the declination. Since the *sāyana* Sun is within 6 *rāśis*, the declination is north.

Example 3 (c). The sāyana Moon is $9^r0°0'$. Its latitude is 4°N. Find its declination.

The *sāyana* longitude being $9^r0°$ 0′, the mean declination is the maximum, south, i.e. 24°S. Its lat. is 4°N, i.e. of opposite direction. ∴ the true declination is 24° − 4° = 20° S. South because South is greater.

The author uses the word *kāṣṭhā* to signify declination, which is uncommon. Sometimes this word itself is used to mean sine declination.

The rule for sin declination is explained thus: Our *siddhāntas* take the maximum declination to be 24°. As the maximun declination occurs when the *sāyana* longitude is 3 signs, the angle between the ecliptic and the celestial equator (i.e. the obliquity of the ecliptic) also is 24°. In Fig. 5, take AB and AC as parts of the ecliptic and celestial equator. Then, A = 24° and AB is the *sāyana* longitude. BC is the declination wanted. By formula II under the present verse, sin dec. = long. × sin 24° ÷ 120′. But sin 24° ÷ 120′ = 48′ 48″ ÷ 120′ = 61/150. Hence, sin dec = sin long × (60 ÷ 1)/150, which is the given rule.

Now for the direction: See Fig. 4. At r the Sun moving along the ecliptic crosses the celestial equator, and passes from South to North. As great circles bisect one another, till the longitude is 6 sings it moves north of the celestial equator, for which declinations are reckoned, and then moves south of it. Therefore for longitude 0 to 6 *rāśis*, the declination is North, and for longitude 6 to 12 *rāśis*, it is South.

As the Moon and other planets move in their own orbits inclined to the ecliptic, the declinations computed from their longitudes reckoned along the ecliptic are only approximate. To get correct declinations, their distances north or south from the ecliptic points, called their 'latitudes', should be combined in the proper manner as instructed. But the result by thus adding or subtracting will be only approximate, because the latitudes are directed towards the pole of the ecliptic (*Kadamba*), while the declinations are directed towards the Celestial Pole. The maximum error that can occur thus is about 24′. Combined with the error in latitude due to other factors like proportion by degrees of the argument of latitude (advocated by the *Pauliśa*) instead of the sine etc., the error will be considerable.

Now, for the readings. For syntactical purposes, and getting the proper meaning, *śatārṃśāśsaikā* has been corrected as *śatāmśaghnaikā*, *ṣaṣṭidineśa* as *ṣaṣṭirdineśa*, *kāṣṭhānta* as *kāṣṭhā jyā*, *apakramarāśi* as *apakramo rāśi* and *pādenyaḥ as pādebhyaḥ*. As for TS, they have not touched this verse and the next two, saying, in so many words, that they cannot interpret them. NP's interpretation of the three verses has also been affected by the highly corrupt text.

लिप्ताशत[क]म(शीत्या) मेषे 'त्रिख' यु(क्त) 'मिन्द्रिय' 'मनू' (न)म् ।
गवि ('मनु') 'भव' 'मुनि' 'रूपै'-श्च[तु]र्गुणैः संयुतं च शतम् ॥ १७ ॥

नवतिस्त्रियुता षष्टिश्चत्वारिंश'च्छिवा'श्च मिथुना(न्ते) |
मेषाद् गताऽऽगतमुदग्दक्षिणतोऽदस्तुलादिषु च || १८ ||

17-18. The (promised) intervals of declinations in minutes for intervals of quarter-signs, are, in Sāyana Meṣa: 180 + 3, 180 + 0, 180 − 5, 180 − 14, in Sāyana Vṛṣabha, 100 + 4 × 14, 100 + 4 × 11, 100 + 4 × 7, 100 + 4 × 1, and in Sāyana Mithuna, 90, 63, 40 and 11. (Thus the intervals are 183, 180, 175, 166, 156, 144, 128, 104, 90, 63, 40, 11.) These are to be added successively to get the declinations from Meṣa (Aries) to Mithuna (Gemini). Then from Karkaṭaka (Cancer) to Kanyā (Virgo), these should be deducted in the reverse order, until at the end of Kanyā, the declination is zero. These declinations from Meṣa to the end of Kanyā are north. Then from Tulā (Libra) to the end of Dhanus (Sagittarius), the south declinations increase in the given order, and from Makara (Capricorn) to Mīna (Pisces) the south declinations decrease in the reverse order, until at the end of Mīna the declination is zero again.)

Example 4. Find the declination of the ecliptic point ending (Sāyana) Capricorn.

The end of Capricorn is *rāśi* 10-0-0. This falls between *rāśis* 6 and 12. ∴ The declination is south. The declination ending Sagittarius (i.e. beginning Capricorn) is 24° S. The declination at the end of Capricorn is 24° − 11′ − 40′ − 63′ − 90′ = 24° − 3° 24′ = 20° 36′S.

The author has perhaps computed the declination by applying the formula of verses 16 and got the intervals by deducting the previous from the next. Or, these verses are taken in toto from the original *Pauliśa* and given here, for there are small differences from the computed values. Or, the differences are scribal errors. Both are given hereunder for comparison:

Degrees	0		7½		15		22½		30		37½		45	
Declinations by formula	0		183		363		537		704		860		1003	
Intervals		183		180		174		167		156		143		127
Given intervals		183		180		175		166		156		144		128
Declinations	0		183		363		538		704		860		1004	

17a. A.B.C. शतमसीत; D. ०मशीतिं
b. A. दशस्त्रिषयुक्रमिंद्रियमनूनां;
B. दशस्त्रिंशायुक्तांमिन्द्रियं (B1. य) मनुनां;
C. दस्त्रिषयुक्तमिन्द्रियमनूनाम् ।
D. दशत्रिसंयुक्तामिन्द्रियमनूनाम् ।
c. A.B.C. गविसेमनुभवमुनि-; D. गवि मनुभवमुनि
d. A.B.C. रूपैश्च गुणैः; D. रूपैश्च [त्रि] गुणैः. B. वशतं

18a. B. षष्टि
b. B. Haplographical om. छिवाश्च [om. to यवश्च in verse 19] याम्योत्तरे कार्ये; C. मियुनान्तरे
c. D. मेषादितो गत उदग्
d. C. तुलादिषट्केषु

Degrees	52½		60		67½		75		82½		90
Declinations by formula	1130		1237		1324		1388		1427		1440
Intervals		107		87		64		39		13	
Given intervals		104		90		63		40		11	
Declinations	1132		1236		1326		1389		1429		1440

Bearing the need for agreement in mind, the syllables *ka, tu* have been inserted in verse 17 to make up for deficiency in syllables; *āsīt ta* has been corrected into *aśītyā* for the sake of sense, as also *deśastriṣa* into *mese trikha, manūnām* into *manūnam,* and *gaviṣe* into *gavi;* and *ntare* has been corrected into *nte* to delete one syllable, and also make the word sensible.

In the manuscripts, after *catvārimśacchivāśca* in the 18th verse, the end of the 19th, *yāmyottare kārye* and the beginning of the 20th, *Viṣuvaddina(? va)samadhye* have strayed. Only after these is found the end of the 18th, *mithunāntare(? nte).* The portion from here, upto *na divānisi* in V.9, is missing in one set of manuscripts.

[शङ्कुच्छाया]

(शङ्कुचतुर्वि)स्तारे वृत्ते छायाप्रवेशनिर्गमनात् |
नपरैन्द्रीदिक्सिद्धि(र्य)वा(च्च) याम्योत्तरे कार्ये || १९ ||

Gnomonic shadow

19. (Plant a gnomon at the centre of) a circle having a diameter equal to four times the gnomon. Mark the two points where the shadow of the gnomon enters the circle and emerges from it. The line joining the points is the east-west line. The line drawn perpendicular to this by means of equal intersecting circles, is the north-south line.

Though the east-west line is first asked to be drawn and the north-south next, as perpendicular bisector to the east-west, it will be better if the north-south line is first drawn by means of equal intersecting circles with the two points as centres. Then using the points of intersection of the north-south line and the original circle as centres, by the same means, the perpendicular bisector forming the east-west line can be drawn, which will pass through the centre as required. On the other hand, if the east-west line is first drawn by joining the first two points, another line parallel to it and passing through the centre is to be drawn as the desired east-west line.

19a. A. संकुश्चतुविस्तारे; C. शङ्कङ्गुलविस्तारे
c. A. अपरैद्री; C.D. अपरैन्द्री
d. A. यवाश्च; C.D. यवैश्च
· B. After कार्ये one leaf missing upto दिवा in V. 9c. as noted by the scribes. Thus, B1 adds in the margin, प्रति पत्र एक; B2. adds, प्रतिपत्र एके, and B3. adds प्रति नूं पत्र एक. And all add अग्रो नास्ति ।

The gnomon should be twelve units in length, not necessarily digits; no harm will result, provided all measurements are given in the same units. The circle also can be of any desired diameter, not exactly four gnomons in length. We are not sure whether the word for 'four' occurs at all in the text, it is so corrupt in that part. We can only say it cannot be *śaṅkvaṅgula* as corrected by TS; the letters are so different.

Finding the directions in the manner described is explained thus: The North is directed towards the north pole of the earth. Corresponding to this is the celestial north pole, (from which we can find the north, if we can only observe it correctly, and therefrom the other directions). At mid-day the Sun is on the meridian, and at equal times before and after, its altitudes and directions are equal, provided its declination does not change. As the Sun's position is thus symmetrical, before and after noon, with the meridian as the line of symmetry, the gnomonic shadow is symmetrical with the north-south line (which corresponds to the meridian) as the line of symmetry. Therefore if two gnomonic shadows, one in the morning and one in the evening, of equal lengths, are marked on a horizontal surface, the bisector of the angle between the two shadows is the line of symmetry, and therefore the north-south line. From this the east-west line, which is its perpendicular bisector, is drawn. The circle, asked to be drawn, serves the purpose of marking the equal shadows. By the same symmetry, the ends of the shadows are at equal distances from the east-west line, and so the line drawn between them is also east-west, being parallel to the east-west line drawn. Therefore the author asks us to draw the east-west line formed by joining the two points first, and proceed. We have said that the Sun's declination must be the same, i.e. does not change during the interval. But actually it changes. So if we do the work at a time of the year when the change in declination is very little, then the directions found will be nearly accurate. This happens near the solstices, and therefore the work should be done when the sun is near the solstices. Methods to find the directions accurately even when the declinations are changing rapidly, are given by writers like Vaṭeśvara, Parameśvara etc., and also explained by Govindasvāmin in his commentary on the *Mahābhāskarīya*, III.1.

[छायातः अक्षानयनम्]

विषुवद्दिन [सममध्य] च्छायावर्गात् सवेदकृतरूपात् |
मूलेन शतं विंशं विषुवच्छायाहतं छिन्द्यात् || २० ||
लब्धं विषुवज्जीवा चाप [म] तोऽक्षोऽ [थवैव] मिष्टदिने |
मेषाद्यपक्रमयुतस्तुलादिषु विवर्जितः स्वाऽक्षः || २१ ||

Latitude from Shadow

20. Measure the mid-day shadow on the day when the Sun is at the equinoxes (the equinoctial shadow), square it, add 144, and find the square root. By this divide the product of the shadow into 120.

21. The result is the sine of the latitude of the place, called *Viṣuvajjīvā* (or *Viṣuvajyā*). Its arc is the latitude. Or, do this work on any day and get the arc. If the Sun is in the six signs from *sāyana*-Meṣa, i.e. if the Sun's declination is north, add the declination to the arc, the latitude is got. If the Sun is in the six

signs from *sāyana*-Tulā, i.e. if the declination is south, subtract the declination from the arc, the latitude is got.

That is:

i. Sine latitude = $120' \times$ equinoctial shadow $\div \sqrt{144 + \text{equinoctial shadow}^2}$. The arc from this is the latitude.

ii. Sine south zenith distance of the Sun, (SZD) = $120' \times$ mid-day shadow $\div \sqrt{144 + \text{midday-shadow}^2}$. The arc of this is the SZD.

Using SZD, Latitude = SZD$\pm$declination ('*plus*' should be used if the declination is north, and *minus* if south.)

Example 5 (a). At a certain place the equinoctial shadow is 5 units. Find the latitude of the place.
Sin. lat. = $5 \times 120' \div \sqrt{5^2 + 144} = 600' \div 13 = 46'\ 9''$.
Arc of $46'\ 9'' = 22°\ 37'$. The latitude is $22°\ 37'$.

Example 5 (b). At a place when the Sun is at the end of sāyana Tulā, the mid-day shadow is found to be 9 units. Find the latitude of the place.

From the formula, (the mid-day-Sun's) sin SZD = $9 \times 120' \div \sqrt{9^2 + 144} = 1080'/15 = 72'$.

SZD = arc of $72' = 36°\ 53'$.

The declination of the Sun at the end of Libra is 11° 44′S (from 16-18). Taking the minus sign, since the declination is south, the latitude = $36°\ 53' - 11°\ 44' = 25°\ 9'$.

Note: Rule (i) can be used everywhere, while rule (ii) should be used only if the midday sun is south of the zenith. If it is north, having north zenith distance, (NZD), declination = NZD = latitude. But the work being a *Karaṇa,* the author intends it to be used only in North India, where the midday zenith distance is always south, and hence this has not been mentioned by him. Further the author envisages only north latitudes by his formulae.

Sky-sphere (Khagola)

Here onwards, explanations require a knowledge of the sky-sphere (*khagola*) with the stellar sphere imposed on it. Therefore we shall describe the sky sphere. Hindu astronomers describe it as the 'Casket Boundary of our universe' (*Brahmāṇḍa-kaṭāha-sampuṭa*), and marked by the penetration of sunlight. Beyond that there is no sunlight. The measure of a great circle on the sky-sphere is said to be the number of *yojanas* the Moon, or the Sun or any planet moves in a *kalpa* (*yuga* according to the followers of Āryabhaṭa), — though, really, the sphere is only illusory and supposed to have an indefinite radius. As the stellar sphere also is enormous, we can take the surfaces of the two spheres sliding on each other, and forming spherical triangles by arcs on each intersecting those on the other. The problems will entail the solution of these triangles. (The formulae for solution have already been given). This will be understood by examining Fig. 6.

20-21. Quoted by Utpala on *BS* 2. pp. 59-60.
20a. A. सममधृष्टो; C. दिनमध्याह्नो
b. A. om-रूपात्र-om.
c. A. शते. A.D. विंशत्
d. A.C.D. छिंद्यम्
12b. A. चापतोक्षो. A.C.D. ०थवा यथेष्टदिने
d. A. स्वोक्षः

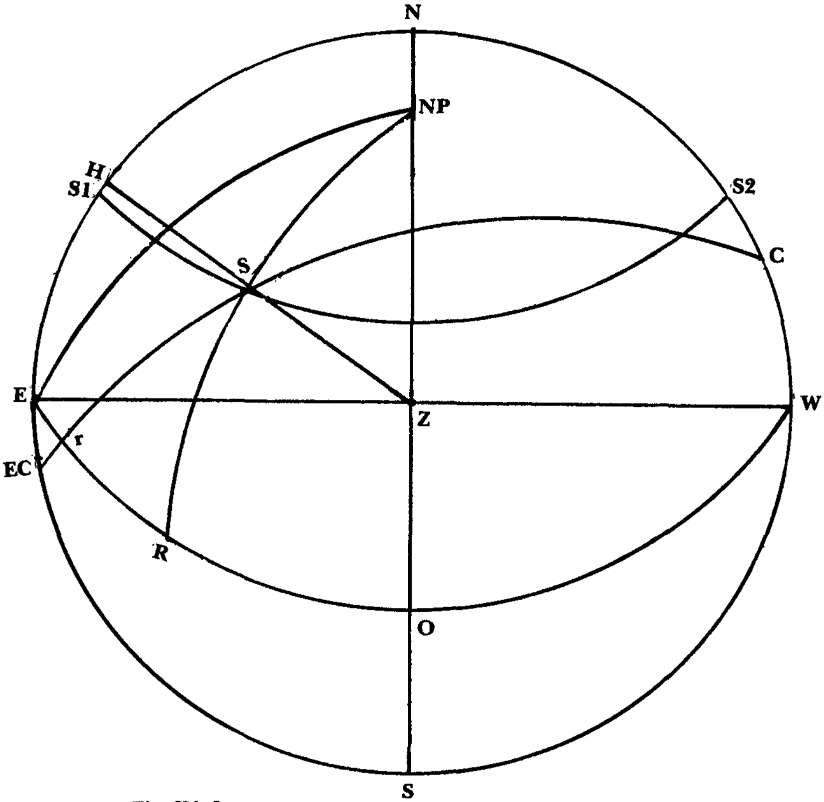


Fig. IV. 6

NESWZ is the sky-sphere. It is the sky as seen by an observer on the earth who fancies himself stationary, though taking part in the rotation of the earth, and thinks that the stellar sphere is rotating on the axis joining the celestial poles, NP, SP. NESW is the horizon marked by the cardinal points, North, East, South, West. (Note that the east and west points are interchanged so as to appear as we see them when looking up at the sky.) Z is the zenith, corresponding in the sky to the observer's position on the earth, and is the point where the line from the centre of the earth, through the observer, joins the sky-sphere. NNPZOS is the meridian. EZW is called the prime vertical. ENP is part of what is called *unmaṇḍalam*. ZSH is part of the vertical circle from the zenith to the horizon passing through the sun, moon, etc. (Note that the prime vertical is the vertical circle passing through the east and west points, and that the meridian itself can be considered as a vertical circle passing through the North and South points.) ZS is the zenith distance of S, and HS is the altitude. S_1SS_2 is the diurnal circle, the apparent path of S daily, due to earth's rotation.

The stellar sphere (Fig.4) can be recognised here by the celestial equator ErROW, by the ecliptic EcrSC, by the north celestial pole NP, by the position of the Sun S, etc. and by the declination circle. NPSR, of which SR is the arc of declination. Because of the position of the observer on the earth with reference to the terrestrial North pole, the celestial North pole (NP) seems lifted up along the meridian from the north-point (N) so that its altitude is equal to the latitude of the place, and by this the celestial equator is depressed southward by the same amount from the prime vertical.

Therefore the latitude of the place = NNP = ZO. (What we have said is for places in the northern hemisphere, i.e. north latitudes. In the southern hemisphere, i.e. at places of south latitudes, SP is lifted up from S, and the celestial equator is depressed northward by the same amount.) The complement of ZO, OS, is called the co-latitude (*Lamba*). Thus in triangles formed by great-circle-arcs of the stellar sphere and the sky-sphere, the latitude is involved directly or indirectly. The formulae for the solution of these triangles have been already given.

Now, the two formulae for latitude can be proved by using the meridian, thus: see Fig.7

Ob:observer
N: north point
S: south point
$NS_2ZS_1OS_oS_3$: The meridian
Z: zenith
O: point of intersection of meridian and celestial equator.
S = S_2, S_1, S_o, S_3,: four positions of the mid-day sun.
OS: Sun's declination

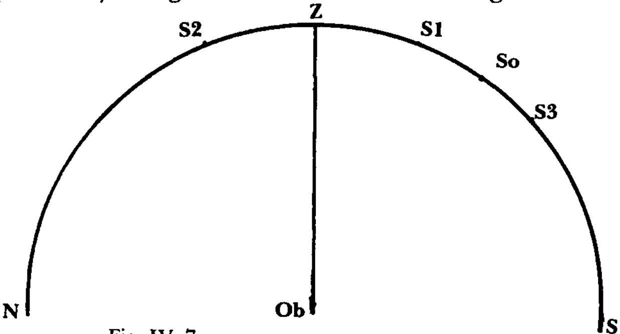


Fig. IV. 7

As already described, OZ = latitude.

On the equinoctial days at mid-day the Sun, S_0 is at O.

∴ ZS_o (the south zenith distance of the Sun) = ZO = latitude (first formula).

On other days, the Sun may be (i) south of O, (S_3), or (ii) north of O but south of Z, (S_1), (iii) north of O and north of Z, (S_2).

i. Here, the latitude = OZ = $S_3Z - S_3O$ = the south zenith distance of the Sun — the declination. (second part of second formula).

ii. Here the latitude = OZ = $ZS_1 + S_1O$ = the south zenith distance of the sun + the declination (first part of the second formula).

iii. Here the latitude = ZO = $S_2O - S_2Z$ = the declination − the north zenith distance of the Sun. (This case is not given by the author).

The zenith distance of the midday Sun used in the formulae is to be found thus: see Fig.8.

EG = gnomon of 12 units
ET = The midday shadow,
TG = The shadow hypotenuse,
ZGS = the zenith distance = angle TGE.

Sin zenith distance (ZD) = sin ZGS= sin TGE= TE × 120′ ÷ TG

= Shadow × 120′ ÷ Shadow hypotenuse
= Shadow × 120′ ÷ $\sqrt{\text{shadow}^2 + \text{gnomon}^2}$
= Shadow × 120′ ÷ $\sqrt{\text{shadow}^2 + 144.}$,
(where shadow is in the units taken).

From sin ZD, arc ZD is found.

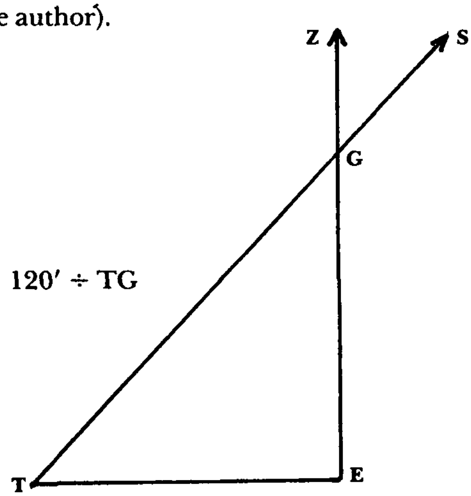


Fig. IV. 8

[मध्याह्नच्छाया]

अपमोनयुताऽक्षज्यां त्रिज्यातत्कृतिविशेषमूलेन ।
छिन्द्याद् द्वादशगुणितां लब्धा माध्याह्निकी छाया ॥ २२ ॥

Sine zenith distance

22. Subtract the Sun's declination from the latitude (of the place), if the declination is north, and add if it is south. The midday Sun's Z.D. is got. Find its sine and multiply by twelve. Divide this by the root of the difference of the squares of the radius and sine ZD. The mid-day shadow is obtained in *aṅgulas*.

The following are the rules:

i. Degrees of zenith distance = Latitude $\mp$ Sun's declination (the upper sign being used for north declination and the lower for the south.)

ii. Mid-day shadow $= 12 \times \sin ZD \div \sqrt{120^2 - \sin^2 ZD}$ (where 120 is written for radius).

It must be noted that the incompleteness mentioned in connection with the second formula if the previous work is found here too.

Example 6. The latitude of a place is 25° 9′. The Sun's declination is 11° 44′, south, (the Sun being in the part of the ecliptic beginning from Libra). Find the mid-day shadow.

The declination being south, ZD = 25° 9′ + 11° 44′ = 36° 52′. Sin ZD = 72′.

$\therefore$ Midday shadow $= 12 \times 72 \div \sqrt{120^2 - 72^2} = 12 \times 72 \div 96 = 9$ *aṅgulas*.

The rules are explained thus:

From the previous rule, Latitude = zenith distance $\pm$ declination, (+ for north declination, and − for south declination), we have, zenith distance = latitude $\mp$ declination, (for north and south declinations, respectively).

From this sine zenith distance is got. Using this, the shadow is obtained from the previous rule, $\sin ZD = \text{shadow} \times 120 \div \sqrt{\text{shadow}^2 + 144}$.

Squaring both sides, $\sin^2 ZD = \text{shadow}^2 \times 120^2 \div (\text{shadow}^2 + 144)$.

$$\sin^2 ZD \times (\text{shadow}^2 + 144) = \text{shadow}^2 \times 120^2$$
$$\sin^2 ZD \times \text{shadow}^2 + 144 \sin^2 ZD = \text{shadow}^2 \times 120^2$$
$$120^2 . \text{shadow}^2 - \sin^2 ZD . \text{shadow}^2 = 144 \sin^2 ZD$$
$$\text{shadow}^2 = 144 \sin^2 ZD \div (120^2 - \sin^2 ZD)$$
$$\text{shadow} = 12 \sin ZD \div \sqrt{120^2 - \sin^2 ZD}.$$

22. Quoted by Utpala on *BS* 2, p.61.

22a. A.D. अयनोन. A.C.D. U. ॰क्षज्या

b. A. तात्रिक्रति; C.D. U. तत्त्रिज्याकृति. A. मूला

c. A.C.D. गुणिता

d. A. माध्याह्नकी

[लम्बज्या दिनव्यासश्च]

विषुवज्ज्याऽऽयामार्धवर्गविश्लेषमूलमवलम्बकः |
क्रान्तित्रिज्याकृत्योरन्तरपदं द्विगुणं दिनव्यासः || २३ ||

Sine Co-latitude and Day-diameter

23. Square the sine of latitude and deduct from the square of the radius. Its square root is the 'sine of co-latitude', (its arc being the 'co-latitude'). Square the sine of declination, deduct from the square of the radius and find its root. Twice the result is the 'day diameter'.

Now, we have

(i) sine co-latitude = $\sqrt{\text{radius}^2 - \sin^2 \text{latitude}}$

(ii) Day-diameter = $2 \times \sqrt{\text{radius}^2 - \sin^2 \text{declination}}$

Example 7 (a). sin lat. = 72. Find sin co-lat, and its arc, viz. the co-lat.

sin co-lat. = $\sqrt{120^2 - 72^2} = 96'$.
Arc 96′ = 53° 8′ = co-latitude.

Example 7 (b). The Sun is at the end of the sign Aries. Find the day-diameter.
The Sun's longitude = *rāśi.* 1-0-0. Sine *rāśi.* 1-0-0 = 60′.
∴ sin declination = 60′ (60+1)/150 = 24′ 24″.
The day-diameter = $2 \times \sqrt{120^2 - 24' 24''^2} = 2 \times 117' 30'' = 235'$.

In the right angled triangle having the radius as the hypotenuse and the sine of latitude as the base, the sine of the co-latitude stands as the perpendicular or *lamba*. Therefore it is called *lambajyā*. By the analogy with co-sine for sine, co-tangent for tangent, and co-secant for secant, the term co-latitude for latitude, has been invented for 90′−latitude, for convenience of expression. Therefore: (since base^2 + perpendicular^2 = hypotenuse^2), $\sin^2$lat + $\sin^2$ co-lat = radius^2.
From this, $\sin^2$ co-lat = radius^2 − $\sin^2$ lat.
∴ sin co-lat = $\sqrt{\text{radius}^2 - \sin^2 \text{lat}}$.

As for the day-diameter, by the diurnal rotation of the earth on its axis, the Sun apparently moves round the earth every day in a circular path, at a distance from the celestial equator equal to the latitude, with the axis of the earth perpendicular to the plane of the circle. This circle is called the diurnal circle or day-circle and its diameter, the day-diameter. (See this shown in Fig.6.) The diameter can be measured thus: see Fig.9.

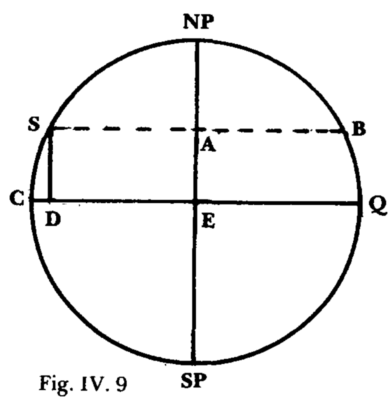


Fig. IV. 9

23. Quoted by Utpala on *BS* 2, p. 60.
23a. A. विवच्छायामात्यार्द्ध
b. A. मूलवले लबः; C. मूलभवो लब्धः
c-d. A. °क्रान्तिज्यात्रिज्याक्रांत्यन्तरपदं; C-D. °कृत्यन्तरात् पदाद् दिनव्यासः (D. पदद्विदिनव्यासः)
d. A. द्विदिन

NPCSPQ is the stellar sphere, with centre E, CQ is the celestial equator, SC is the declination of the Sun S, SEC = degrees of declination, SB is the diurnal circle, with the straight line SB as its diameter, and SA as its radius.

Suppose the sphere is cut into equal halves, with the cross section NP C SP Q E exposed to view and the axis NP E SP forming a diameter.

SE is the radius, and SD (= AE) = sin declination. Then, $SA = \sqrt{SE^2 - SD^2}$.

But SA = half day-diameter.
$\therefore$ day-diameter = 2 SA
$= 2\sqrt{\text{radius}^2 - \sin^2 \text{declination}}$.

अजवृषमिथुनापक्रमजीवाः (षड्घ्नाः स्यु) 'वेंद-मुनि-वसवः' |
त्र्यष्ट'तिथि' षट्का(ष्टक)विकलाऽभ्यधिका[:] परिज्ञेयाः || २४ ||

24. The sines of declinations of the points of the ecliptic ending Aries, Taurus and Gemini are 24′ 24″, 42′ 15″, and 48′ 48″.

We shall show these to be correct by computing them. The sine declination of the end of Aries, *i.e. rā.* 1-0-0 has been derived in example 7(b) to be 24′ 24″. The sine of declination of the end of Gemini, i.e. *rāśi* 3-0-0, has been shown to be 48′ 48″, (the maximum) in the example above. So we shall derive here only sine declination of the end of Taurus, i.e. *rāśi* 2-0-0. Sine *rāśi.* 2-0-0 = 103′ 55″ (from tables). The sine of its declination by IV.16 is, 103′ 55″ × (60 + 1)/150 = 41′ 34″ + 41″ 34‴ = 42′ 15″34‴. Here, though 34‴ is greater than half a second, the author has omitted it and given 42′ 15″, to the nearest quarter minute.

[पञ्चत्रिंशत्] त्र्यष्टकसरूपधृ[तिसंयु]ता क्रमाद् द्विशति |
पञ्चाष्टक'तिथि'विकलाधिकौ वृषा(न्त्यौ) दिनव्यासः || २५ ||

25. The respective day-diameters are, in the minutes parts: 200 + 35, 200 + 24, and 200 + 19, with 40″ and 15″ added to the second and third, (i.e. the day-diameters are, 235′, 204′ 40″ and 219′ 15″).

Of these, the day-diameter of the end of Aries has been worked out in *Example 7 (b).* We shall derive the other two.

The day-diameter for the Sun at the end of Taurus = $2\sqrt{120^2 - \sin^2 \text{declination of the end of Taurus}}$,
$= 2\sqrt{120^2 - 42'\,15''^2} = 224'\,38''$.

24b. A.C.D. षड्घ्नास्तु
c. A. षट्काषट्; D. षट्काष्ट[क]विकला
d. A. ०धिका प

25a. A. om पञ्चत्रिंशत्
b. A. ०धृता क्रमा. C.D. द्विशती
d. A. ०धिको. A. वृषात्यौ

But the author gives 224′ 40″ as being more convenient to use. The day-diameter at the end of Gemini = $2\sqrt{120^2 - 48'48''^2}$ = 219′ 15″, which is the same as given by the author.

The missing part of the text, (*pañcatriṁśat*), has been found out by computation. (*tisaṃyu*) has been guessed as being necessary to supply the meaning, which is clear.

[चरः]

व्या(स)क्रान्तिज्याघ्नी विषुवज्या लं[ब]कद्युदैर्घ्यहृता।
तच्चापकलात्र्यंशश्चरखण्डविनाडिकाः स्पष्टाः ॥ २६ ॥

Cara

26. Multiply the sine of latitude by 240′ and by the sine of declination. Divide by the sine of co-latitude and by the day-diameter. Find the arc of the sine obtained in minutes—(This arc is called half-*cara*)-and divide by 3. The result are the accurate minutes of *cara*, (which might be called 'day-difference'). From the *cara* we can obtain the *cara*-intervals, (or *cara* differences).

This is the formula:

(i) Sine half-*cara* = 240′ × sine latitude × sine declination ÷ (sine co-latitude × day-diameter)

From this the half-*cara* arc is got. Then,

(ii) *Cara*, i.e. day-difference in *vināḍis* = minutes of half-*cara* ÷ 3.

In III.12 the author gave a rule for the *cara-vināḍis* to be used in North-India and its neighbourhood and said that he would give the general rule later in the *Chedyaka* section. This is it. Further, in the rule of III.10, the interval of the *vināḍis* were given for long intervals in degrees, like whole signs, and the value obtained can only be rough. This rule can give accurate values.

The reading perhaps is *'cara-piṇḍa'* for which the scribe has written *'cara-khaṇḍa'* by mistake.

Example 8. The sine of latitude of a place is 72′, and the sine of co-latitude 96′. The Sun is at the end of Mithuna, with the sine of its declination 48′ 48″. The day-diameter for the day is 219′ 15″. Find the cara-vināḍis.

By the formula, sine half-*cara* = 240′ × 72′ × 48′ 48″ ÷ (96′ × 219′ 15″) =40′ 4″.

Arc 40′ 4″ = half-*cara* = 19° 31′ = 19 × 60′ + 31′ = 1171′.

Cara-vināḍis = 1171/3 = 390, i.e. *nāḍis* 6-30.

The work is thus explained: (See fig.10)

26a. A.व्यासः क्रान्ति
b. A.ज्यालक

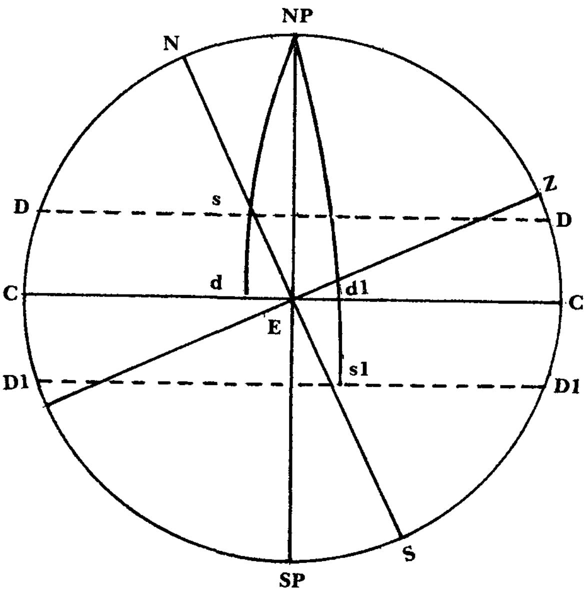


Fig. IV. 10

In the stellar sphere CEC is the celestial equator, NP and SP being the north and south poles. NESP is the *Unmaṇḍala* or horizon of a place on the equator. Z is the zenith of the place, N and S being the north and south points and E is the east point.

DsD is the day-diameter of the Sun, (s), in the northern hemisphere, making the declination sd. $D_1s_1D_1$ is the day-diameter of the Sun, (s_1), in the southern hemisphere, making the declination sd. D S D is the day-diameter of the Sun (s_1), in the southern hemisphere, making the declination s_1d_1. s and s_1 are the rising points of the Sun as seen from the place, $NsEs_1S$ being its horizon. The altitude of the North Pole. N NP = angle NE NP, is the latitude, which is equal to SE SP, from which it is seen that for places in the northern hemisphere, the *Unmaṇḍala* is raised from the horizon by this angle in the north, and depressed by this angle in the south. As the Sun, in its diurnal circuit, takes exactly half a day to move from the eastern *Unmaṇḍala* to the western, the day-time is longer when the Sun's declination is north, for it has to travel, after rising, an arc in the diurnal circle (equivalent to the great circle arc dE) to reach the *Unmaṇḍala* and an equal time while setting. The time is less when the declination is south, because before rising it has to travel less by an arc equivalent to Ed_1 to reach the horizon from the *unmaṇḍala* (and an equal time less while setting). dE and Ed_1 are the arcs of half-*cara*. Therefore when the declination is north, the time corresponding to 2 DE in the day-difference, (the day time being greater than 30 *nāḍikās* by this amount,) and when it is south the time equivalent of 2 Ed_1 is the day-difference, (the day-time being less than 30 *nāḍikās* by this amount). So we have to calculate dE, and Ed_1.

In $\triangle$ dEs, right angled at d, by fundamental formula III, sin dE = Radius $\times$ sin Sd $\times$ Cos sEd $\div$ (Cos sd $\times$ sin sEd).

But, sd is the declination and sEd = 90° − N E NP= 90° − latitude.

$\therefore$ sin half-*cara* = 120′ $\times$ sin dec $\times$ cos (90°− lat.) $\div$ {(Cos dec $\times$ sin (90° − lat)}]

$= 120'$ sin dec × sin lat ÷ {(Cos dec × sin (90° − lat)}
$= 120'$ sin dec × sin lat ÷ (day-radius × sin co-latitude)
$= 240'$ sin dec × sin lat ÷ (day-diameter × sin co-latitude).
From this the arc dE is got.

Ed_1 for south declination is got in the same way, from △ $s_1 E d_1$.

From dE or Ed_1, the *cara-vināḍis* are got thus: For the whole circle of 360° or 21600 minutes of arc, there are 60 × 60 = 3600 *vināḍis*. ∴ For the arc of half *cara* in minutes there are 3600 × arc of half-*cara* ÷ 21600 = arc of half *cara*/6 *vināḍis*. The whole *cara-vināḍis* are twice this, and equal to 2 × **minutes of half-*cara*/6** = minutes of half-*cara*/3.

As we have said, these are added to 30 *nāḍikās* to find the day-time, when the declination is north, i.e. when the Sun is in six signs from Aries. Those *vināḍis* are subtracted when the Sun is in the south, *i.e.* in the six signs Libra etc.

The part of the formula, sin declination × sin-latitude ÷ sin co-latitude, is called 'Earth sine', (*kṣitijyā*), in Hindu astronomical works, which is required to be multiplied by the radius and divided by the day-diameter to get sin half-*cara*. In certain works the half-*cara* itself is called *cara*.

[चराद् अक्षानयनम्]

चरखण्डः' (ख)पक्षां'शज्याघ्नमहर्व्यासमुद्धरेत् 'खजिनैः' |
द्विः कृत्वा तद्वर्गात् क्रान्तिज्याकृतियुतान्मूलम् || २७ ||
तेन विभजेत् स्थितज्यां व्यासार्धगुणामवाप्तमक्षज्या |
नवतेरक्षोनायाः क्रमशो ज्या लम्बको भवति || २८ ||

Latitude from Cara

27. Divide the *vināḍis* of *cara* by twenty and find the sine of the resulting degrees. Multiply the day-diameter by this, and divide by 240. Put the result in two places. In one place square it and add the square of the sine of declination and find its root.

28. Multiply the result kept in the other place by the radius, and divide by this root. The result is the sine of latitude. Its arc is the latitude. 90′ *minus* latitude is the co-latitude, and its sine, sine co-latitude.

The following is the work to be done:

i. The *vināḍis* of *cara* ÷ 20 = degree of half-*cara*. Find its sine.

ii. Sine half-*cara* × day-diameter ÷ 240 = sine x. (This is earth-sine or *kṣitijyā*).

27-28. Quoted by Utpala on *BS*, 2, p.60.
27b. A. °महस°
c. A. व्यावृद्धि कृत्वा; C. भूजीवां कृत्वा तत्
d. A. मूलम्

28a. A. थितिज्यां; C.D. क्षितिज्यां. A. पक्षज्या
c. A. नवतेरक्षोसोनाया

iii. Earth-sine × 120 ÷ $\sqrt{\sin^2 \text{earth-sine} + \sin^2 \text{dec}}$ = sin lat. From this the latitude is found

iv. 90° — latitude = co-latitude. Its sine. co-lat.

Example 9. At a certain place on a certain day, the vināḍis of cara are 390 1/3. The day-diameter is 219′ 15″. Find the latitude of the place, and sine co-latitude.

The sine of declination required for the formulae is, by (IV.23), $\sqrt{120^2 - (219' 15''/2)^2}$ = 48′ 48″.

i. Degree of half-*cara* = 390 1/3 ÷ 20 = 1171/(3 × 20) = 19° 31′. From this, sine half-*cara* = 40′ 4″.

ii. (Earth)-sine = 40′ 4″ × 219′ 15″ ÷ 240′ = 36′ 36″.

iii. Sin lat = 36′ 36″ × 120′ ÷ $\sqrt{36' 36''^2 + 48' 48''^2}$ = 120 ÷ $\sqrt{1 + 16/9}$ = 120′ × 3/5 = 72′.

From this, lat = 36° 52′.

iv. Co-latitude = 90° − 36° 52′ = 53° 8′. From this sine co-latitude = 96′.

The rules are thus derived:

a. From the rule, *vināḍikās* of *cara* = minutes of half-*cara* ÷ 3. By transposing, we have: Minutes of half-*cara* = *vināḍikās* of *cara* × 3.

Degrees of half-*cara* = *vināḍikās* of *cara* × 3/60 = *vināḍikās* of *cara*/20, which is (i).

b. From the rule, sine half-*cara* = sin lat. × 240 × sin dec ÷ (sin co-lat x day-diameter), we get;

Sin dec = sin half-*cara* × sin co-lat. × day-diameter ÷ (240 × sin lat)

= sin co-lat × earth-sine ÷ sin lat.

Using this in (iii) above, we have:

Sin lat = earth-sine × 120′ ÷ $\sqrt{\text{earth-sine}^2 + \sin^2 \text{co-lat} \times \text{earth-sine}^2 \div \sin^2 \text{lat}}$.

120′ ÷ $\sqrt{\sin^2 \text{lat} + \sin^2 \text{co-lat} \div \sin^2 \text{lat}}$.

= earth-sine × 120′ ÷ (earth-sine) $\sqrt{1 + \frac{\sin^2 \text{co-lat}}{\sin^2 \text{lat}}}$

= 120′ ÷ $\sqrt{\sin^2 \text{lat} + \sin^2 \text{co-lat} \div \sin^2 \text{lat}}$.

= 120′ ÷ $\sqrt{1/\sin^2 \text{lat}}$ = $\sqrt{\sin^2 \text{lat}}$ = sin lat, thus proving (iii).

From this the latitude is got. Then,

∵ latitude + co-latitude = 90°,

Co-latitude = 90° − latitude.

It should be noted that of the sin declination and the day-diameter required in the rules, one is sufficient, because the other can be got from that. As for the word *khaṇḍa*, meaning 'interval' or 'difference', we have already said that it is *piṇḍa* ('the whole') we get first, and thence the *khaṇḍa*.

As for the reading, we have corrected, *carathaṇakapakṣārṁśa*, into *carakhaṇḍakhapakṣāṁśa*, making *ka* into *kha*, because 'twenty' is required here as the divisor. This is the only correction we have made. But TS, followed by NP, have made several corrections, not realising that if Bhaṭṭotpala's reading is adopted no other correction would be required.

[लङ्कोदयराशिमानम्]

[राशिज्या]ऽपक्रमज्या(कृ)तिवि(श्ले)षमूल[हत] वि(स्ता)रात् |
द्यु(व्या) स(हृ) ता (च्चापं) 'दिग्घ्नं' राश्यु(द्ग)मविनाड्यः || २९ ||
'वसुमुनिपक्षा' 'व्येकं शतत्रयं 'त्रिद्विकाग्नय' [श्चाङ्का] (त्) |
परतस्त एव वामाः षडुत्क्रमात्ते तुलाद्यर्धे || ३० ||

Rt. ascensional difference

29. Square the sine of the longitude of a point on the ecliptic, and deduct from it the square of the sine of the declination of the point. Find its root, multiply it by the diameter and divide by the day-diameter. Find the arc of the resulting sine in degrees. Multiply the degrees by 10. The Right ascension of the point is obtained in *vināḍis*. deducting the right ascension of the next *rāśi* from that of the previous, the right ascentional difference of the *rāśis* are obtained.

30. The *vināḍis* of right ascentional difference for the three signs from Meṣa are 278, 299 and 323. In the next quadrant they are the same in the reversed order, *viz.* 323, 299 and 278. In the half of ecliptic beginning from Libra, the difference are those of the first half, taken in the reverse order.

The formula is:

Sin Right ascension $= 240' \times \sqrt{\sin^2 \text{longitude} - \sin^2 \text{dec}} \div$ day-diameter.

The degrees of right ascension multiplied by 10, are the *vināḍis* of right ascension.

The differences as calculated, are, for Aries etc. 278, 299, 323, 323, 299, 278, 278, 299, 323, 323, 299, 278.

Now, what is the meaning of saying that in the second half the differences are in the reverse order of those in the first half, when reversing the order does not make any difference? True. But the author must have meant this statement for ascensional difference in general, for, then, owing to the subtraction and addition of half day-differences (*carārdha*) in the first and second quadrants, the reverse order becomes different.

Further, the *vināḍis* mentioned here are sidereal and not mean solar, because the *vināḍis* per degree are obtained by dividing the time of a full revolution by 360, and the time of a full revolution of the stellar sphere is a sidereal day, and not a mean solar day which is the time of the diurnal revolution of the mean Sun.

30. Quoted by Utpala on BS 2, p.61.

29a. A. भपक्रमज्या; C. मेषाद्यपक्रमज्या; D. भापक्रमज्या

b. A. क्रतिविशेषमूलविस्तारात्; C. कृतिविश्लेषमूलगुणविस्तरात्; D. कृतिविश्लेषमूल [गणिताद्] विस्तारात्

c. A. द्युद्वासहृताचाप; C.D. द्युव्यासहृताच्चापं

30b. A. ॰काग्रयश्चाजान्; C.D. ॰काग्रयश्चाजात्. U. श्चाङ्काः C.A. वाभाः

d. A. षड्गक्रमास्ते नुताद्यर्द्धे

Example 10. Find the right ascensions of the points of the ecliptic ending Aries, Taurus, and Gemini, i.e. longitudes 30°, 60° and 90°. From them find their respective differences.

Sin 30° = 60′, sin 60° = 103′55″ and sin 90° = 120′.

Sin dec. of the points ending Aries etc. are, respectively, 24′24″, 42′15″ and 48′48″. The respective day-diameters are 235′, 2244′38″, and 219′15″.

(a) For the point 30°, sin Rt. asc = $\sqrt{60'^2 - 24'\,24''^2} \times 240 \div 235 = 54'\,49'' \times 240 \div 235 = 55'\,59''$. Its arc = 27° 49′. Multiplying by 10, the *vināḍis* of Rt. asc. are 27° 49′ × 10 = 278.

(b) For the point 60°, sin Rt. asc. = $\sqrt{103'\,55''^2 - 42'\,15''^2} \times 240 \div 224'\,38'' = 94'\,57'' \times 240' \div 224'\,38'' = 101'\,26''$. Its arc = 57° 42′. The *vināḍis* of Rt. asc. = 57° 42′ × 10 = 577.

(c) For the point 90°, sin Rt. asc. = $\sqrt{120'^2 - 48'\,48''^2} \times 240' \div 219'\,15'' = 109'\,37''.5 \times 240' \div 219'\,15'' = 120'$. Its arc = 90°. The *vināḍis* of Rt. asc. arc. 90° × 10 = 900.

The difference for Gemini = Rt. asc. for 90° − Rt. asc for 60° = 900 − 577 = 323

The difference for Taurus = Rt. asc. for 60° − Rt. asc. for 30° = 577 − 278 = 299.

As the Rt. asc. of the first point of Aries is zero, the difference for Aries = Rt. asc. for 30° − Rt. asc. for 0° = 278 − 0 = 278.

All these are the same as given by the author.

This is how the formula is arrived at: The time taken by each sign of the ecliptic, beginning from Aries, to rise above the eastern horizon, for an observer on the equator, is in *vināḍis* 278, 299, etc., and their total is the time taken by any point to rise, after the rising of the First point of Aries. This is represented by the arc of the celestial equator (called the Rt. asc.) measured from the First point of Aries, and we have to find this arc.

In Fig. 11, r is the First point of Aries. P is the point on the ecliptic of which the time of rising is required, and Pd is the declination of the point, equal to the arc of the horizon from the east point to the rising point. dr is the arc on the celestial equator, called the Right-ascension of the point P, which is required to be found.

From the fundamental formula iv,

Sin Rt. asc. = sin dr = sin Pd × cos Prd × Radius ÷ (Cos Pd × sin Prd)

= sin Pr × cos Prd ÷ cos Pd (∵ by the fundamental formula ii, sin Prd = sin Pd × radius ÷ sin Pr.)

$= \sin Pr \times \sqrt{\text{Radius}^2 - \text{Radius}^2 . \sin^2 Pd \div \sin^2 Pr} \div \cos Pd$

$= \sin Pr \times \text{Radius} \sqrt{\sin^2 Pr - \sin^2 Pd} \div (\sin Pr \times \cos Pd)$

$= \text{Radius} \times \sqrt{\sin^2 Pr - \sin^2 Pd} \div \cos Pd$

$= 120' \times \sqrt{\sin^2 \text{long.} - \sin^2 \text{dec.}} \div \tfrac{1}{2}$ day-diameter

$= 240' \times \sqrt{\sin^2 \text{long.} - \sin^2 \text{dec.}} \div$ day-diameter.

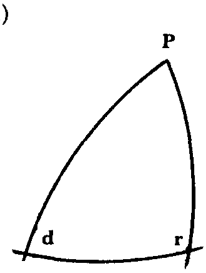


Fig. IV. 11

The arc of this is the Rt. asc. As there are 3600 *vināḍis* for a Rt. asc. of 360°, for the **Rt.** asc. got, the time is, Rt. asc. × 3600 ÷ 360 = Rt. asc. × 10. Then by subtracting the *vināḍis* pertaining to the Rt. asc. of the beginning of the sign from that of the end of the sign, the differences are got.

Because the sine of the longitude and the sine of the declination (which itself varies as the sine of the longitude) decrease in the second quadrant in the reverse order of the increase in the first, and this increase and decrease are repeated in the third and fourth quadrants, the differences of *vināḍis* follow the same course.

[राश्युदयः]

चरदलकालक्षीणास्त्रयस्त्रयः संयुताः प्रतीपैस्तैः |
उदयर्क्षतुल्यकालेन यान्ति तत्सप्तमाश्चास्तम् || ३१ ||

Rising Signs

31. Take the differences of Rt. asc. of three signs at a time. From the first triplet subtract the differences of half-*caras*, one by one, taken in the given order. Add the half-*cara* differences one by one, taken in the reverse order, to the second triplets. To the third triplet add the half-*cara* differences taken in the given order. From the fourth triplet subtract the half-*cara* differences one by one, in the reverse order. The *vināḍis* of the rising signs, called the ascensional differences, as seen from any place, are obtained. The seventh from the rising signs set during the same time as the signs themselves rise.

The ascensional differences for the several signs are as follows:

Aries	: 278 − half-*cara* difference for Aries
Taurus	: 299 − half-*cara* difference for Taurus
Gemini	: 323 − half-*cara* difference for Gemini
Cancer	: 323 + half-*cara* difference for Gemini
Leo	: 299 + half-*cara* difference for Taurus
Virgo	: 278 + half-*cara* difference for Aries
Libra	: 278 + half-*cara* difference for Aries
Scorpio	: 299 + half-*cara* difference for Taurus
Sagittarius	: 323 + half-*cara* difference for Gemini
Capricorn	: 323 − half-*cara* difference for Gemini
Aquarius	: 299 − half-*cara* difference for Taurus
Pisces	: 278 − half-*cara* difference for Aries

It can be noted that the ascensional differences for the six signs, Libra etc., are those of the six signs Aries etc. taken in the reverse order, as mentioned by us earlier. It should also be noted that signs Aries etc. mentioned here are *sāyana*. For *nirayana meṣa* etc. (reckoned from the first point of Aśvinī) the differences, obviously, will be different, and there will not be this symmetry about the first point of Meṣa or Tulā. Also, we have already said that the *vināḍis* are sidereal. Note also, that for places on the equator, the ascensional differences are those given in IV.30 itself, because the

31. Quoted by Utpala *BS*, 2, p.61.
31a. A.C.D. चरकालदशक्षीणा; (C.D. दल)
b. A. प्रतीपैस्ते
d. A. नयन्ति. B. ०माश्चास्तान्

cara is zero there, the day-time being always 30 *nāḍis* there. The Sanskrit name *'Laṅkodaya'* itself suggests this, Laṅkā representing a place on the equator.

Example 11. At a certain place the equinoctial shadow of a twelve-unit gnomon is 5 units. Find the ascensional differences of the twelve āsis. (sāyana).

By III.10 the *cara-vināḍis* – differences for the place, pertaining to Aries, Taurus and Gemini, are $5 \times (20, 16\frac{1}{2}, 6\frac{3}{4}) = 100, 82\frac{1}{2}, 33\frac{3}{4}$. The half-*cara* differences are, respectively, 50, 41, 17 *vināḍis*. in the southern hemisphere it is the other way. It is called *Unmaṇḍala* because it is raised in one's

Aries	: 278 − 50 = 228	Libra	: 278 + 50 = 328
Taurus	: 299 − 41 = 258	Scorpio	: 299 + 41 = 340
Gemini	: 323 − 17 = 306	Sagittarius	: 323 + 17 = 340
Cancer	: 323 + 17 = 340	Capricorn	: 323 − 17 = 306
Leo	: 299 + 41 = 340	Aquarius	: 299 − 41 = 258
Virgo	: 278 + 50 = 328	Pisces	: 278 − 50 = 228

The procedure is thus explained: The horizon of a place on the equator (i.e. zero latitude) appears raised towards the north pole to a person in the northern hemisphere on account of the elevation of the pole as we go north and submerged towards the submerged south-pole. To a person in the southern hemisphere it is the other way. It is called*Unmaṇḍala* because it is raised in one's own hemisphere. The Right ascensional differences having reference to the horizon of zero latitude, i.e. the *unmaṇḍala*. But what we want are the ascensions, i.e. risings from the horizon of the place. Therefore the risings are earlier when the declination of the *rāśi* is north, (for places in the northern hemisphere), by the time the Sun takes to move from the horizon to the *unmaṇḍala* along the diurnal circle, and later by the same time when the declination is south. It has been explained that this time is equal to the half-*cara vināḍis*. So, with reference to the points of the triplet Aries, Taurus and Gemini, whose declination is north, the half-*cara* has to be deducted. As the declination increases, *rāśi* by *rāśi*, the differences of half-*cara* have to be subtracted one by one, until the maximum half-*cara* is reached. There the declination decreases as it has increased, still being north, and the half-*cara* which has to be deducted decreases in the same manner. So the differences are added in the reverse order in the second triplet, i.e. Cancer, Leo and Virgo. In the next triplet, viz. Libra, Scorpio and Sagittarius, the south declination increases, i.e. the additive half-*cara* increases, and to the half-*cara* differences are again added, in the regular order, because in the third triplet the south declination increases in the same manner as the north declination in the first triplet. Then in the fourth triplet, i.e. Capricorn, Aquarius and Pisces, the south declination decreases, i.e. the additive *cara* decreases, and so the differences have to be deducted. (All this can be seen clearly on a globe). From the explanation it can be seen that for places in the southern hemisphere, the risings of the *rāśis* are those of their seventh in the northern hemisphere.

As great circles intersect one another, the part of the ecliptic above the horizon is always half a great circle, and therefore the distance between the rising point and the setting point of the ecliptic is always six signs, as also that of the celestial equator. Therefore the change in the Rt. asc. of the setting point of the ecliptic is equal to that of the rising point, with the result that the time of the setting of a sign seventh from the rising point is that of the rising point.

[उन्नतकालः]

इष्टोत्तरगोलापक्रमांशकज्यां 'खभास्करा'भ्यस्ताम् ।
हृत्वाऽक्षजीवया तच्चापादुदयेन तत्कालः ॥ ३२ ॥
तस्मिन् दिनकृत् कुरुते सममण्डलसंश्रयं दिनाद्यर्धे ।
तावच्छेषे परतो न तुलादिषु विद्यते चैतत् ॥ ३३ ॥

Time to reach the Prime vertical

32. When the Sun is within 6 signs from Aries, (i.e. when the Sun's declination is north), multiply the sine of the declination by 120′ and divide by the sine of the latitude, (the place being presumed to be north of the equator also). The sine of the Sun's altitude at Prime vertical, (*śama-śaṅku*), is got. Find its arc. Treat this arc as part of the ecliptic, and find its Rt. ascension in *vināḍis*.

33. This is the time taken by the Sun to reach the Prime vertical in the forenoon after crossing the *unmaṇḍala*, and the time remaining to reach it after reaching the Prime vertical, in the afternoon. The Sun does not touch the Prime vertical when it is in the six signs beginning from Libra, (i.e. when the declination is south), (as seen from places in the northern hemisphere).

The following is the work asked to be done:

(i) Sin altitude at Prime vertical = 120′ × sin dec ÷ sin lat.

(ii) Sin rt. asc. = $\sqrt{\sin^2 \text{alt} - \sin^2 \text{dec}} \times 240' \div$ day − diameter.
Find the arc of this.

(iii) Arc in degrees × 10 = time in *vināḍis* to reach the prime vertical from the *unmaṇḍala* (or vice versa in the afternoon)

(iv) Add the total half-*cara vināḍis* if the time from sunrise, (or to set, if afternoon) is wanted.

Here, the author has not mentioned the work of ii-iv explicitly, intending to give it subsequently. But it is clear that he is giving the time connected with the prime vertical, and that too, not the time before noon or afternoon, but the time from sunrise or to sunset. But it is not mentioned whether the rising or setting is with reference to the horizon of the place or to the *unmaṇḍala*. But as the rt. ascension in the manner of computing the Laṅkodaya is clearly meant, rising or setting with reference to the *unmaṇḍala* alone seems to be in the author's mind, for the time with reference to that alone can be got. So to get the time from actual sunrise or sunset, the half-*cara* has got to be added, (section iv of the work), though this is not mentioned by the author. The half-*cara* has already been given, and need not be computed afresh.

32-33 Quoted by Utpala on *BS*. 2, p.41.
b. A. ज्या. A. तस्कराभ्यस्तां; D. भास्करव्यस्तां
c. A. हृताक्ष. A. जीवजात
d. C. यत्कालः

33b. A. संश्रया. A1. दिनाद्यर्द्धे; A2. दिनाद्यर्थ्रू; U. दिनाद्ये वा
d. A1. चैतत्र

It may be mentioned in this connection that TS understand here only the work upto finding the sine of altitude at Prime vertical. As for the time, they say it is equal to the time taken by the Sun to reach the altitude found out, when the question is how to find this very time.

It should also be noted that the work upto finding the sine of rt. ascension mentioned in (i) and (ii) can be done easily, thus: Work (iv) presupposes the knowledge of sin half-*cara*. Using that, sin rt. ascension mentioned in (ii)

= sin half-*cara* $\times$ $\sin^2$ colat $\div$ $\sin^2$ lat.

= sin half-*cara* $\times$ 144 $\div$ square of equinoctial shadow.

If the sin rt. ascension obtained is greater than 120′, then, even when the Sun's declination is north, the Sun does not touch the prime vertical. We shall explain this later.

Example 12. On a certain day, the longitude of the Sun is rāśi 1-15. The latitude of the place (north of equator) is 30°. (The equinoctial shadow is 6 aṅgulas 55.7 vyaṅgulas). When, after sunrise, does the Sun cross the prime vertical at that place, on that day.

We require the sine of declination and sine half-*cara* for the given time and place.

Sin dec = sin $1^r\ 15° \times 61/150$ = sin $45° \times 61/150$ =
 $= 84'\ 51'' \times 61/150 = 34'\ 30''.3$.
The day-diameter $= 2 \times \sqrt{120^2 - 34'\ 30''.3^2} = 229'\ 51''.4$
Sin half-*cara* = 240′ $\times$ sin lat $\times$ sin dec $\div$ (sin co.lat. $\times$ day-diameter)
 $= 240' \times 60' \times 34'\ 30''.3 \div (103'\ 55'' \times 229'\ 51''.4)$
 $= 20'\ 48''$.
Half-*cara* = arc of $20'\ 48'' = 9°\ 59'$.
Half-*cara vināḍis* arc $9°\ 59' \times 10 = 100$ = *nā*.1-40.

All this is supposed to be known already.

Now for the computation of the time:
(i) sin altitude $= 34'\ 30''.3 \times 120' \div 60' = 69'\ 1''$.

(ii) sin rt. asc $= \sqrt{69'\ 1''^2 - 34'\ 30''.3^2} \times 240' \div 229'\ 51''.4 = 62'\ 24''$. Its arc is $31°\ 21'$.

(iii) The corresponding time $= 31°\ 21' \times 10 = 313$ *vināḍis* = *nā*. 5-13.

(iv) The time of crossing the prime vertical after sunrise = *nā*. 5-13 + *nā*. 1-40 = *nā*. 6-53.

This is for the forenoon. For the afternoon, deducting this time from the time of sunset, *nā*. 33-20, the time of crossing is *nā*. 33-20 − *nā*. 6-53 = *nā*. 26-27.

Now, according to the short-cut in the place of (i) and (ii), Sin rt. asc. = sin half-*cara* $\times$ $\sin^2$ co.lat $\div$ $\sin^2$ lat.
 $= 20'\ 48'' \times 103'\ 55''^2 \div 60'^2 = 20'\ 48'' \times 3$.
 $= 62'\ 24''$. (See this obtained by the regular rule).
Or, sin rt. asc. = sin half-*cara* $\times$ 144 $\div$ equinoctial shadow
 $= 20'\ 48'' \times 144 \div$ (6 *aṅg*. 55.7 *vyaṅg*.)^2
 $= 20'\ 48'' \times 3\ 62'\ 24''$, as already obtained.

The rules are explained as follows, supposing the place to be north of the equator. (For places south of the equator also the same can be used, interchanging the directions north and south, wherever they occur.) See Fig. 12.

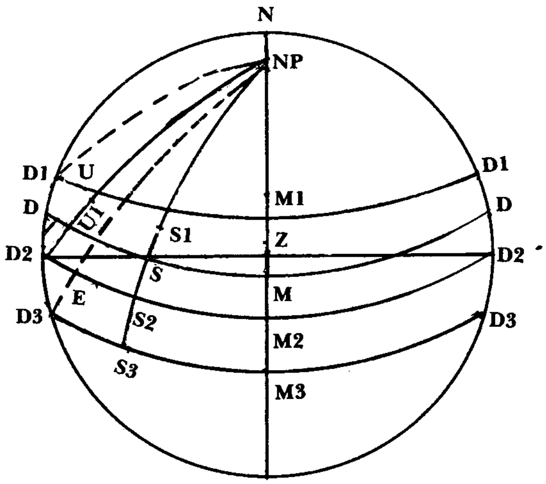


Fig. IV. 12

In this figure of the sky-sphere, Z is the zenith, and NP is the north pole. D_1D_1, DD, etc. are four diurnal circles, on which four positions of the sun, S_1, S, etc are indicated.

$D_2M_2D_2$ is a part of the *unmaṇḍala*, visible.

In all the diurnal circles, the Sun S_1 etc. rising at D_1 etc. moving westwàrd, moves a little south, little by little, until it reaches the meridian point M_1 etc., where the 'southing' is equal to the latitude, N NP, and then proceeds to move westward, moving north little by little, setting in the west at a point having the same amplitude as the rising point, (assuming that the declination does not change). On the two equinoxes, the Sun rises due east (D_2) and sets due west (D_2) southing on the meridian by ZM_2 (= N NP = latitude), and thus is always south of the prime vertical. So, when the declination is south, the diurnal circle (D_3D_3) is always south of the prime vertical and so the Sun (S_3) never touches the prime vertical. Even when the declination S_1S_2 (= M_1M_2)is greater than the latitude (ZM_2) then the Sun is always north of the prime vertical, the diurnal circle $D_1S_1M_1D_1$ being north of it. It is this that was referred to by us as the case not mentioned by the author, *viz.* the case of the declination being north, but still not crossing the prime vertical, the case that is possible in the southern part of India. There is only one case left, that of the Sun's declination being north, but less than the latitude, (e.g. the Sun moving on the diurnal circle D U S MD), in which alone the Sun crosses the prime vertical as at S.

The time by which the Sun rising at D describes the part of the diurnal circle, DS, is to be found. Here there are two parts, the time from D to U which is the half-*cara*, and the time from U to S, i.e. the time after crossing the *unmaṇḍala*, which alone, we have said, has been mentioned explicitly by the author, and for which alone the rules of computation have been given by him. That is why we have said that the two times should be combined to get the time after sunrise. Of these, the method for computing the half-*cara* has been explained already. Therefore we shall explain the second part alone.

The time to move from U to S in the diurnal circle is clearly the time to move from D_2 to S_2 on the celestial equator, and given by the arc D_2 S_2 which is to be got by solving the spherical triangle

SS_2D_2, right angled at S_2. SS_2 is the declination. Angle $S_2D_2S = ZM_2$ = latitude. Therefore, from the fundamental formula IV,

$$\sin D_2S_2 = \text{Cos } S_2D_2S \times \sin SS_2 \times \text{radius} \div (\sin S_2D_2S . \cos SS_2)$$
$$= \text{Cos lat} \times \text{sin dec} \times \text{radius} \div (\text{sin lat.} \times \text{cos dec.})$$
$$= \text{sin colat} \times \text{sin dec} \times \text{radius} \div (\text{sin lat} \times \text{day-diameter}/2)$$
$$= \text{sin colat} \times \text{sin dec} \times 240' \times (\text{sin lat.} \times \text{day-diameter})$$

(From $\sin D_2S_2$ arc D_2S_2 is found and converted into time at 10 *vināḍis* per degree, as mentioned before.)

We shall prove the author's method by showing that his formula is equal to this. The author's formula is:

$$\text{Sin } D_2S_2 = \sqrt{\sin^2 \text{alt. at prime-vertical} - \sin^2 \text{dec}} \times 240 \div \text{day-diameter}$$
$$= \sqrt{\sin^2 \text{dec} \times 120^2 \div \sin^2 \text{lat} - \sin^2 \text{dec}} \times 240 \div \text{day-diameter}$$
$$(\because \sin D_2S = \sin SS_2 \div \sin S_2D_2S, \text{ by fundamental formula II})$$
$$= \sqrt{(\sin^2 \text{dec} (120^2 - \sin^2 \text{lat}) \div \sin^2 \text{lat}} \times 240 \div \text{day-diameter.}$$
$$= \sqrt{\sin^2 \text{dec.} \sin^2 \text{colat} \div \sin^2 \text{lat}} \times 240 \div \text{day-diameter}).$$
$$= \text{sin dec} \times \text{sin colat} \times 240 \div (\text{sin lat} \times \text{day-diameter})$$

This is identical with the formula derived by us. (The author himself will be giving this form in the next verse.)

We shall now show how the formula for the condensed work is got. The formula for half-*cara* is:

Sin half-*cara* = sin dec × sin lat × 240′ ÷ (sin colat × day-diameter)

Multiplying the numerator and the denominator of the formula arrived at by (sin lat × sin colat), we have,

Sin Rt. asc. = sin declination × sin lat × $\sin^2$ colat × 240 ÷ ($\sin^2$ lat × day-diameter × sin colat)
= sin half-*cara* × $\sin^2$ colat ÷ $\sin^2$lat, given by us.

Again, $\sin^2$ colat ÷ $\sin^2$ lat.
= 120′ × 12 ÷ equinoctial hypotenuse^2 ÷ (120′ × equinoctial shadow ÷ equinoctial hypotenuse)^2
= 12^2/equinoctial shadow^2
= 144 ÷ square of equinoctial shadow.
So this can be substituted for $\sin^2$ colat ÷ $\sin^2$ lat.

It must be noted that if the declination is greater than latitude, i.e. if sin dec > sin lat, then sin colat > day-diameter. Therefore sin rt. asc. > 120′, for which there is no arc, which means that at no altitude, or at no time does the Sun cross the prime vertical. This is what was referred to earlier and here shown mathematically.

'(ख)जीन'घ्नी क्रान्तिज्या लम्बघ्नी ध्रुवगु(ण)द्युदै(र्घ्यहृता) |
तच्चाप(स्य) 'रसां'शः सक[ा]लः (स) दि(वस)वृद्ध्यर्धः || ३४ ||

34. Multiply sine declination by 240 and again by sin co-latitude and divide by the product of the sine of latitude and day-diameter. Find its arc in degrees and divide by six. (The time in *nāḍis*, taken by the Sun to move from

the *unmaṇḍala* to the prime vertical is got.) Add to it the time of half-*cara*. This is the time from sunrise for the Sun to reach the prime vertical.

The following is the work:

(i) Sin (arc corresponding to time from *unmaṇḍala* to prime vertical) = 240 ′ × sin dec × colat ÷ (sin lat × day-diameter)

(ii) The arc in degrees of (i) is to be got. Dividing by 6, the time in *nāḍīs* is got.

(iii) The time got by (ii) + the half-*cara* is the time after sunrise, for the Sun to cross the prime vertical.

Note that the formula here given is what we arrived at earlier, as what the author's formula reduces to in verses 32-33. Then, why is this repetition? In the previous two verses, the work was not given clearly and fully. Here it is clear and full.

Now for the reading: From the words *khajinaghnī krāntijyā lambaghnī*, it is clear that the product of two sines must be the divisor. Therefore, we have corrected *dhruvaguṇa dyudairghyahṛtā* into *dhruvaguṇa-dyudairghya-hatā*, which is otherwise also a better reading. Other small corrections have been made according to the idea intended to be expressed, and according to syntax. Thus it is clearly seen that in the work sin colat appears as part of the numerator, and sin lat. as part of the denominator, from which it can be seen clearly that the formula is concerned with finding the time of the Sun's rise from *unmaṇḍala* to the prime vertical, and not the half-*cara*. The mention of the half-*cara* here is just to say that it should be added to find the whole time.

However, both TS and NP have been misled by the mention of the expression 'half-*cara*' into thinking that the formula itself is to find the half-*cara*, with the result that they take the numerator as the denominator, and the denominator as the numerator, not realising that by their interpretation the rule for half-*cara* would be a repetition, because in IV. 26 also the same has been given, and in the same form, which NP, too, have, noticed and observe: "This in fact, is only a repetition of IV. 26. It is here out of place." (pt.II, p.43). But it may be asked whether the work according to our interpretation is not a repetition of the work of the previous two verses. We say the work as given here is clear, succinct and full. But when what is the use of the two previous verses? The work there given is easy to explain on the basis of the rule for the Rt. ascension of the ecliptic point, gone before. Or, that method perhaps is that of the Pauliśa, the author giving the same in a better form here.

The example on this has already been worked out in Example 12.

[समशङ्कुः तच्छाया च]

उत्तरगोलेऽर्कज्या काष्ठा(न्त)गुणा ध्रुवज्यया भक्ता |
ताः शङ्कुलिप्तिकाऽऽख्यास्ताभिः सममण्डल(च्छा)या || ३५ ||

34a. A1.षजिनघ्नी; A2.त्रजिनघ्नी
b. C.D.लम्बहृता घ्रुवगुणा. A.ह्रितात्
c. A.तच्चापंश
d. C.D.सकल
A.दिनवृद्ध्यर्द्धः; C.दिवसवृद्ध्यर्द्धः;
D.दिन[वि]वृद्ध्यर्धः

Great gnomon (Sama-śaṅku) and its shadow

35. When the Sun is in the northern hemisphere, (*i.e.* in the six signs, Aries etc.), multiply the sine of the longitude of the Sun by the sine of the maximum declination, (i.e. by 48′ 48″), and divide by the sine of latitude. The minutes so obtained are called the minutes of the 'Great gnomon' or *Śaṅku,* (i.e. sine of altitude), (and in this case, the sine of Prime vertical altitude). From this the shadow of the Sun on the prime vertical must be calculated.

(i) Sin prime vertical altitude = sin Sun's long × 48′ 48″÷ sin latitude.

This is the Great gnomon, and the radius is the Great hypotenuse. The square root of the square of the hypotenuse lessened by the square of the gnomon is the shadow. Therefore the Great shadow $= \sqrt{\text{radius}^2 - \sin^2 \text{prime vertical alt.}}$

Therefore, by the similarity between the Great shadow and the shadow triangles, we have the proportion, Great gnomon: Great shadow :: Twelve unit gnomon: shadow. From this, the required,

(ii) Shadow $= 12 \times \sqrt{120^2 - \sin^2 \text{prime vertical alt.}} \div$ sin prime vertical altitude.

Example 13. The longitude of the Sun is rāśi 1-0. The latitude is 30°. Find the Great gnomon of the Sun at prime vertical, and thereby the gnomonic shadow at that time.

(i) The Great gnomon = sin prime vertical altitude
= Sin Sun's longitude × 48′ 48″ ÷ sin latitude
= 60′ × 48′ 48″ ÷ 60′ = 48′ 48″.

(ii) Shadow $= 12 \times \sqrt{120^2 - 48'\,48''^2} \div 48'\,48''$
= 12 × 109′ 38″ ÷ 48′ 48″
= 12 × 109 19/30 ÷ (61/150) = 1644 − 30 ÷ 61
= 26 units and 58 parts, *aṅgulas* and *vyaṅgulas*

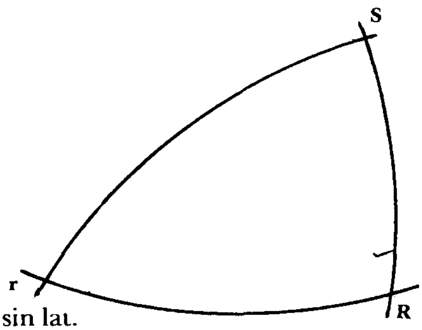


Fig. IV. 13

The equation (i) can be written as,
Sin prime vertical alt. = sin Sun's long.× sin max. dec. ÷ sin lat.
= sin Sun's long. × sin max. dec × radius ÷ (sin lat × radius)
= (sin Sun's long.× sin max. dec ÷ radius) × (radius × sin lat)

Here, it can be shown that sin Sun's long × sin max. dec ÷ radius = sin dec., thus:

Sin Sun's long.× sin max. dec ÷ radius
= sin Sun's long.× 48′ 48″ ÷ 120′
= sin Sun's long.× 61/150
= sin dc. (by IV. 16).
Or, from Fig. 13, thus:

In the triangle right-angled at R, rS is the Sun's long. and SR is the declination of the Sun. SrR is the maximum declination. By fundamental formula II,
sin rS × sin SrR ÷ radius = sin SR.
∴ sin Sun's long.× sin max. dec ÷ radius = sin dec.

35. Quoted by Utpala on *BS* 2, p.42
35b. A. काष्ठान्तरगुणा d. A. मण्डलछाया; U. मण्डले छाया

Now we shall show that sin prime vertical alt = sin dec × radius ÷ sin lat. In Fig.12, SZD_2 is the prime vertical, and the part D_2S is the altitude of the Sun S, and the sine of the altitude is to be found. But, sin D_2S = Cos SZ, since $D_2Z = 90^\circ$, and $SZ = 90^\circ - D_2S$. Observe the triangle S Z NP, right angled at Z. Here, Z NP is the co-latitude. S NP = 90° − SS_2, (∵ NP S_2 = 90°).

Now, from fundamental formula i,

cos SZ = cos S NP × radius ÷ cos Z NP.

∴ sin Pv alt = cos (90° − dec) × radius ÷ cos co-lat

= sin dec × radius ÷ sin (90° − colat)

= sin dec × radius ÷ sin lat.

As stated earlier, the Sun crossing the prime vertical can occur, if at all, only when it is in the northern hemisphere, (of course for north-latitudes) and this is mentioned in the verse by *uttara-gole*.

It should be noted that it is this sin pv. alt that is asked to be derived in IV. 32 by the statement: *iṣṭottaragolāpakramāṃśakajyām khabhāskarābhystām hṛtvākṣajīvayā,* which can be seen by comparing the work. Only, the name *Sama-śaṅku* (i.e. sin pv.alt.) is not mentioned there. So, the arrangement would have been better if the author had first given the formula for sin pv.alt, and then given the time of crossing the prime vertical by either IV. 34 or IV. 32-33, and, last of all, the shadow of the Sun on prime vertical. But the great transcend all restriction! Or, there is plenty of all sorts of errors committed by scribes in this part of the text, as we have reason to think.

[गणकस्य योग्यता]

सममण्डलले(खा)संप्रवेशवेलाः करोति योऽर्कस्य |
तत्प्रत्ययं च जनयति जानाति स भास्करं सम्यक् || ३६ ||
वर्षेण भगणमर्को यदि भुङ्क्ते किं त(तो) यथेष्टदिनैः |
अज्ञोऽप्येवं गणयति किं न रविं लोष्टरेखाभिः || ३७ ||

Astronomer's qualifications

36. Only he is fit to be called an expert astronomer knowing the problems dealing with the Sun, who can compute the time of the Sun crossing the prime vertical, and prove his method mathematically and graphically.

37. Even a person with very little knowledge can, by using pieces of pot-sherds, and strokes tackle (by means of computation) problems like finding the Sun's motion in a desired number of days, given the motion is twelve *rāśis* per year.

The idea is that anybody can tackle problems depending on mere proportion. Only an expert can understand how to solve difficult problems like computing the time of the Sun's crossing the prime vertical, and prove the soundness of his method by means of graphical representations.

36. Quoted by Utpala on *BS* 2, p.42
a. A. लेषा सं°
b. A. वेला; P. U. वेलां. A. करोतिर्योर्कस्य
37b. A. तयो

[शङ्कुच्छाया सममण्डलं च]

कृतदि(ग्ग्र)हणे वृत्ते रेखां पूर्वापरां यदा छाया ।
प्रविशति सम्यक्छङ्कोस्सममण्डलगस्तदा सूर्यः ॥ ३८ ॥

Gnomonic shadow and the prime vertical

38. On a circle with the east-west line drawn, and the directions marked, (according to IV.19), the time when the gnomonic shadow perfectly coincides with the east-west line is the time of the Sun crossing the prime vertical.

The idea is that if this time is found by measuring instruments, compared with the computed time and the agreement shown, people will acquire faith in the method.

It can be shown that when the Sun is on the prime vertical, the gnomonic shadow must be along the east-west line. The prime vertical is the vertical great circle of the sky-sphere, passing through the east-west points and the zenith, and therefore the east-west line forms the intersection of this vertical plane and the plane of the horizon which is horizontal. As the gnomon standing vertical and also the Sun on the prime vertical lie in the vertical plane, the shadow (intercepted by the horizontal plane) must also lie on the vertical plane, and therefore must fall on the east-west line, which is the intersection of the two planes.

[अग्रा-दिग्ज्या]

इष्टक्रान्तिज्या(घ्न)व्यासशकललम्बकांशमुष्णांशुः ।
समपूर्वापररेखामतीत्य यात्यस्तमुदयं वा ॥ ३९ ॥

Agrā : Sine amplitude

39. Multiply the Sun's declination by the radius and divide by the sine of co-latitude, and find the sine (of the amplitude of the rising or setting point, called *Agrā*). At a point distant by this amount from the east-west line (according to the declination, north or south) the Sun rises or sets.

Agrā, (i.e. sine amplitude) = sin dec × radius ÷ sin colat. Find the arc of this sine. By an angle equal to this from the east to west point does the Sun rise or set on the horizon.

Example 14. The latitude of a place is 60°. The longitude of the Sun is rāśi 4-0. Find the direction of rising or setting of the Sun.

First, sin declination is to be found. As the Sun is in the second quadrant, Sin *rāśi* 4-0 = Sin *rāśi* 2-0 = 103′ 55″. Sin dec = 103′ 55″ × 61/150 = 42′ 15″, and this declination is north.

Sin amplitude = 42′ 15″ × 120′ ÷ sin (90° − 60°)
= 42′ 15″ × 120′ × 60′ = 84′ 30″.
= 84′ 30″.

38. Quoted by Utpala on *BS* 2, p.41.

38a. A. कृतिदिग्रहणे

c. A. शङ्कुः

39a. A. ज्याघ्ना; D. ज्याघ्नं

b. A. व्यासकल; D. व्यासशक(लं) लम्बभक्तमुष्णांशुः

d. A1. मतीत्पा; A2. मलि प्त corrected to मलीप्त ।

The arc of 84′ 30″ is 44° 46′. Therefore the Sun rises at a point 44° 46′ north of the east point, and sets at a point 44° 46″ north of the west point, (assuming that the declination has not changed).

The formula for amplitude is got thus: See Fig. 12. Take S_1 as the Sun on the diurnal circle north of equator. Then S_1S_2 is the declination of the Sun, D_1D_2 is the amplitude of sunrise. From the figure it can be seen, $D_1D_2 = 90^\circ - ND_1$ Therefore sin D_1D_2 = Cos ND_1. From the right angled triangle ND NP in the figure, Cos ND can be got thus: By the fundamental formula I,

Cos $ND_1 = 120' \times$ Cos D_1 NP $\div$ Cos N NP.
But, Cos D_1 NP = Cos S_1 NP = Cos $(90^\circ - S_1S_2)$ = sin S_1S_2
= sin S_1S_2
Cos N NP = sin $(90^\circ -$ N NP) = sin colat.
∴ Sin amplitude = $120' \times$ sin dec $\div$ sin colat.

When the Sun is south of the celestial equator, (e.g. S_3 in the figure), D_3 is the rising point, and D_2D_3 is the amplitude. Its sine is got thus, from the triangle, D_2D_3E, right-angled at E. By the fundamental formula II,

Sin D_2D_3 = sin $ED_3 \times$ radius $\div$ sin angle D_3D_2E,
Here, ED_3 is the declination.
$D_3D_2E = 90^\circ - ED_2Z = 90^\circ -$ lat.
∴ sin amplitude = sin declination $\times$ radius $\div$ sin $(90^\circ -$ lat)
= sin dec $\times$ radius $\div$ sin co-lat., which is the formula given.

[अग्राया अक्षानयनम्]

तेन हता 'खार्क'घ्नी क्रान्तिज्या लम्बकोऽस्य [य] (च्चा) पम् ।
तेन नवतिर्विहीना (यच्छेषं) तेऽक्षभागाः स्युः ॥ ४० ॥

Latitude from Agrā

40. Multiply sine declination by 120 and divide by the sine of amplitude. The sine of co-latitude is got. Find its arc in degrees. Deduct the degrees from 90. The remainder are the degrees of latitude.

Now, sin co-lat = $120' \times$ sin dec. $\div$ sin amplitude.
From this, the arc, co-lat is got. $90^\circ -$ colatitude = latitude, as already stated in (IV. 28).

From the formula of the previous verse,
Sin amp = radius $\times$ sin dec $\div$ sin co-lat,
Sin colat = radius $\times$ sin dec $\div$ sin amp. = $120' \times$ sin dec $\div$ sin amp.

From the amplitude of the setting Sun also, the latitude can thus be found. The amplitude can be marked on a circle with the directions already marked by the observation of sunrise or sunset.

40a. A. हता. A. खार्कघ्नी
b. A1. कोस्य श्चापम्; (A2. स्प corrected to स्य)
c-d. A. हीना छ्येधत्तेक्षभागाः

The sine of amplitude to be used in the formula can be got by measuring the arc of amplitude, or the distance of the point, from the east-west line.

Example 15. Sine declination is 42′ 15″. Sine amplitude is 84′ 30″. Find the latitude.

From the formula, sin. colat = 120′ × 42′ 15″ ÷ 84′ 30″ = 60′. Colatitude arc of this, i.e. 30°, latitude = 90° − 30° = 60°.

[इष्टकालच्छाया]

तत्कालचरविनाडीद्विदशांशं द्विष्ठमजतुलाद्येषु ।
[षड्घ्नी]भ्यो नाडीभ्यो जह्यात् संयोजयेच्चाऽपि ॥ ४१ ॥

तज्ज्या स्थितज्यया संयुता विसंयोजिताऽ[जतु]लाद्येषु ।
अविशोधने (च) जीवा षड्घ्नीनामे[व] कर्तव्या ॥ ४२ ॥

एवं कृत्वा हन्यात् द्युव्यासेनाऽवलम्बकघ्नेन ।
छिंद्यात् 'खखाऽष्टवस्वश्विभिः' फलं शङ्कुलिप्ताख्यम् ॥ ४३ ॥

Shadow at desired time

41. To find the gnomonic shadow caused by the Sun at any time: Take the *cara* in *vināḍis* and divide by 20. Degrees of half-*cara* are obtained. Place the degrees in two places. Convert the time from sunrise in *nāḍis* into degrees by multiplying by 6. From these degrees, deduct or add the half-*cara* degrees according as the sun is in the six signs beginning with Mesa or in the six signs beginning with Tula, respectively.

42. Find the sine of the resulting degrees, and add or subtract this from the sine of the half-*cara* kept apart in the second place, according as the Sun is in the 6 signs Meṣa etc., or in the six signs Tulā etc. (The result is a sine. If the half-*cara* degrees cannot be deducted from the time converted into degrees, then simply find the sine of the degrees of sine, and take it for further work.)

43. Multiply this sine by the sine of colatitude and the day-diameter and divide by 28,800. The result is sine altitude of the Sun.

41-44. Quoted by Utpala on *BS* 2, p.61.
41b. A. सदशांशां दिष्टमज
c. A. षघ्नाभ्यो
42a. A. तज्या स्थिज्यया
b. A. °योजिताद्येषु; C.D. योजिताजतुलाद्येषु
c. A. °नेन ज्ञीवा; C-D. U. °नेन जीवा
d. A. षघ्नानामेषकर्त्तव्या (A2. षड्घ्नी)

43a. A. कृचा हन्या
b. A. द्युव्योमेनाव; U. लम्बघ्नेन

A. Haplographical omission of 43 c-d, 44 and 45a-b: लम्बकघ्नेन [... लम्बकघ्नेन] छिंद्यात् Hence they are added here from Utpala's quotaton thereof.

[तत्कृतिविना(कृ)तानां 'खखवेदसमुद्रशीतरश्मीनाम्' ।
पदमर्कघ्नं शङ्क्वङ्गुलाऽऽख्यलिप्तोद्धृतं छाया ॥ ४४ ॥]

44. Square this and deduct from 14,400. Take its square root, multiply this by twelve, and divide by sine altitude. The result is the length of the shadow of the twelve-digit gnomon.

The following are the steps in the work:

(i) Sine altitude = {sine (degrees of the $\mp$ degrees of half-*cara*) $\pm$ sine half-cara} $\times$ sin colat $\times$ day-diameter $\div$ 28,800. (Here, of $\mp$ or $\pm$, the upper sign should be taken for the 6 signs Meṣa etc., and the lower for the 6 signs Tulā etc.)

(ii) The shadow = $12 \times \sqrt{14{,}400 - \sin^2 \text{altitude}} \div \sin \text{altitude}$

Example 16 (a). At a certain place where the sine of the co-latitude (i.e. cos. lat.) is 103′ 55″, when the Sun is in the 6 signs from Meṣa on a particular day, the cara is 200 vināḍis, and the day-diameter is 229′ 51′. Find the length of the shadow at 8 nāḍis from Sunrise.

(i) Degrees of half-*cara* = 200 ÷ 20 = 10°.
Degrees of time = 8 × 6 = 48°.
As the Sun is in the six signs from Meṣa, deducting 10° from 48°, we get 38°. Sine 38° = 73′ 35″. The sine of the half-*cara*, i.e. sin 10° = 20′ 50″. Adding the two signs, (since the Sun is from Meṣa), 73′ 35″ + 20′ 50″ = 94′ 25″.

Sine altitude = 94′ 25″ × 229′ 51″ × 103′ 55″ ÷ 28,800 = 78′ 19″

(ii) The shadow = $12 \times \sqrt{14{,}400 - 78' 19''^2} \div 78' 19''$ = 13 *aṅg* 56 *vyaġ*.

Example 16 (b). At the same place, on the same day, find the shadow at one nāḍi after sunrise.

(i) The degrees of half-*cara* (already found) = 10°. The degrees of time = 1 × 6 = 6°. The half-*cara* degrees have to be deducted, but cannot be deducted, being greater. Therefore, taking the sine of the 6° alone, we have 12′ 32″. Sin altitude = 12′ 32″ × 229′ 51″ × 103′ 55″ ÷ 22,800 = 10′ 24″.

(ii) shadow × $12 \times \sqrt{14{,}400 - 10' 24''^2} \div 10' 24''$ = 137 *aṅgulas* 57 *vyaṅgulas*.

But it should be mentioned here, that the author's instruction for the case when the degrees of half-*cara* cannot be deducted from the degrees of time, will give only a rough result. This will not matter much in places where the degrees of half-*cara* is small, as in India, and therefore given by the author.

For correctness, the following instruction is to be followed. If the degrees of half-*cara* cannot be deducted from the degrees of time, deduct the degrees of time from the degrees of half-*cara*, find its sine, and deduct this from the sine of half-*cara*. This sine should be multiplied by sin colat. etc. and sine altitude is to be got. Because this will not produce much differences in our country, the author has not given this detail. (Even if the *cara* is 5 *nāḍis* the difference in sin alt. will be only 15′.) Further, the measurement of long shadows cannot be accurate, and any inaccuracy caused by the author's rough work will be submerged in the inaccuracy of measurement.

44a. C.D. विनाशकृतानां

We have mentioned that the author's rough procedure is indicated only when the Sun is in the six signs from Meṣa, because only then have we to deduct the degrees of half-*cara*, and the question, what is to be done when the half-*cara* is greater, arises. As for the subtraction of sine half-*cara* in the six signs from Tulā, that will always be less, and the question cannot arise.

TS have not understood the author here, and say something unconnected and useless. (See their commentary p.25, and English Translation, pp.34-35).

The rules, (for the Sun in the northern hemisphere) can be derived thus: (see fig. 14.)

Z = Zenith
P = North pole
E = East point
S = Sun
DD′ = Diurnal Circle
AS = Altitude of the Sun
ZS = zenith distance of the Sun.
EP = *Unmaṇḍalam*
Sin AS = Sin altitude of the Sun
= *Śaṅkuliptās* (or *Mahā Saṅku* or Great gnomon)/120

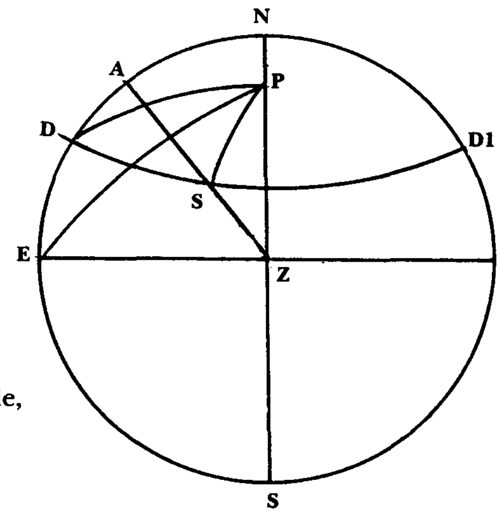


Fig. IV 14

By the well-known formula of the spherical triangle,
Sin altitude of the Sun = sin AS = cos ZS
= cos S P. cos Z P + sin S P. sin Z P. cos PZ.

Here, using the tabular sines,

sin S P = *dyujyā*/120 = diameter of the diurnal circle/240.

sin Z P = sin co-latitude = *lambajyā*/120.

cos S P = sin (90° − SP) = sin declination of the Sun = *krāntijyā*/120.

cos Z P = sin latitude = *akṣajyā*/120.

cos S PZ = sin S PE = sin (D PS − D PE) = sin (degrees of the taken time − degrees of half-*cara*)

∴ *Śaṅkuliptās* (i.e. Great gnomon) = sin declination × sin latitude ÷ 120 + day-diameter × sin co-latitude × sin (degrees of taken time − degrees of half-*cara*) ÷ 28,800.

= day-diameter × sin colatitude × {sin (degrees of taken time − degrees of half-*cara*) + sin declination × sin latitude × 240 ÷ (day-diameter × sin colatitude)} ÷ 28,800

= day-diameter × sin colat. {sin (degrees of taken time − degrees of half-*cara*) + sin half-*cara*} ÷ 28,800

= rule (i) applied to Sun in the northern hemisphere.

In the same manner, the rule can be proved for the Sun in the southern hemisphere, but here the degrees of half-*cara* is first to be added (instead of being subtracted) to the degrees of time, and sin half-*cara* is to be subtracted instead of being added, because here, S PE = D PS + D PE, and these changes have to be made accordingly.

Rule (ii) is derived from the Great gnomon thus: The radius itself being the Great hypotenuse, and the Great gnomon and the Great shadow (this is 120 cos altitude or 120 sin zenith distance) are the sides of the right angled triangle, we have:

Great shadow = $\sqrt{120^2 - \text{Great gnomon}^2}$

Then the shadow of the 12 digit gnomon is found by the proportion: Great gnomon: Great shadow :: 12 digit gnomon : shadow, and we get the rule (ii), shadow = $12 \times \sqrt{14{,}400 - \text{Great gnomon}^2}$ $\div$ Great gnomon.

In this connection, it may be noted that later authors like Bhāskarācārya II give different terms to different sections of the work. For instance they call sin (degrees of taken time ∓degrees of half-*cara*) as *Sūtram*. *Sūtram* ± half-*cara* is called by them *Iṣṭāntyā*. They call *Iṣṭāntyā* × day-diameter ÷ 240 as *Iṣṭahṛti*. Then from *Iṣṭahṛiti* the Śaṅkuliptā is obtained by the proportion: 120: sin colat :: *Iṣṭahṛiti* : *Śaṅkuliptā*, by the similarity of the *akṣākṣetras*.

[छायातः इष्टकालनाड्यः]

[छाया द्वादशकृत्योर्योगान्मूलेन लम्बकघ्नेन |]
'खखवस्व(श्वि)मुनी(न्दून्') (वि) भज्य लब्धा प्रथमजीवा || ४५ ||
त(द्द्युक्रान्ति)ज्याघ्नी विषुवज्या ल(म्ब)कोद्धृता स्थाप्या |
प्रथमज्या विश्ले(ष्या) (मे)षाद्ये(ऽन्यत्र) संयु(क्ता) || ४६ ||
ततस्थि(त)जीवे गुणिते 'खजिनै'र्द्यु(व्या)सभाजिते चापे |
युतवियुतेऽ(ज)तुलादिषु ष(ड्डृ)तो नाडिका लब्धा || ४७ ||

Time after sunrise

45. Square the shadow measured in digits, add 144, and get its square root. Multiply this by the sine of co-latitude and by this product divide 1,72,800. The quotient is called the 'First sine'.

46. Now, multiply the sine of declination of the Sun by the sine of latitude and divide by the sine of co-latitude. (Let us call this by its actual name, the Earth-sine.) Place this Earth-sine in two places. In one place, subtract this from or add this to the 'first sine', according as the Sun is in the northern or southern hemisphere.

47. This result, and the Earth-sine, are each to be multiplied by 240 and divided by the day-diameter. These are two sines. Find the arcs of each of these. When the Sun is in the northern hemisphere add the two arcs. Otherwise subtract one from the other. Divide the result by 6. The result is the time in *nāḍis* after sunrise.

45c. A. वस्वश्च. A. मुनीन्द्रात्; C. मुनीन्दोः; D. मुनीन्दुं
46a. A. तद्युज्याक्तांत्रीज्याघ्नी
c. A. विश्लेषा
d. A. सेषाद्येनात्र संयुत
47a. A. तस्थिति
b. A. खजिनेद्युद्यासभाजिते
c. A. वियुते च
d. A. षद्रुद्धतो; C.D. षड्डृता. A. लब्धा

The following are the steps in the work to be done:

(i) The 'First sine' = 1,72,800 ÷ (sin colatitude × $\sqrt{144 + \text{shadow}^2}$

(ii) The Earth-sine (which is to be placed in two places) = sin latitude × sin declination ÷ sin colatitude.

(iii) sine I = ('First sine' ∓ Earth-sine) × 240 ÷ day-diameter

(iv) sine II = Earth-sine × 240 ÷ day-diameter.

(v) Find arc I and arc II of sin I and sin II

The desired time in *nāḍis* = arc I/6 ± arc II/6. In (iii) and (v) the upper sign is to be taken for the Sun in the six signs from Aries, i.e. for the Sun in the northern hemisphere; otherwise the lower sign is to be taken.

It must be added here, in accordance with what was said in the same context in getting the shadow from the time, that if the 'First sine' is less than the Earth-sine and therefore the Earth-sine cannot be deducted in (iii), the 'First sine' is to be deducted from the Earth-sine, and the result, *i.e.* sine I, is to taken as negative. Then in (v) the *nāḍis* got from this, viz. arc I/6, are also negative, and therefore deducted from arc II/6, to get the time. Here too, if the latitude of the place is not too high, the reverse of the author's method in the context can be used without any appreciable error, though this has not been mentioned here by the author. This is the work to be done: Here the Earth-sine is greater than the 'First sine'; omit the Earth-sine and do (iii) and (v) with the 'First sine' alone, *i.e.* multiply the 'First sine' by 240, divide by the day-diameter, get the arc of this, and divide by 6 and thus to get the *nāḍis* after sunrise.

The following points must be noted here. In the work of computing the *nāḍis* from the shadow, as the exact time is not known, the exact Sun and therefrom the exact declination cannot be known, and we have to use the declination of the Sun at sunrise or sunset. There may be a small error on account of this. This can be avoided by repeating the work using the declination of the Sun for the computed time. It has not been specifically mentioned by the author because this can be inferred by the computer. Secondly, the author has given all this for places in the northern hemisphere in the forenoon. For places in the southern hemisphere and the afternoon, changes have to be made in the work, which have not been given by the author. It must also be noted that the ancients considered the computation of the time from the shadow or the shadow from the time as very important because this was the best means available to them of knowing the times of births and *muhūrtas*.

Example 17 (a) For a place (in the northern hemisphere) sin lat. is 60′, and therefrom sin colat is 103′ 55″. On a particular day the sin declination is 34′ 30″, (the sun being in the 6 signs from Aries) and therefore the day-diameter is 229′ 51″. Find the time from sunrise if the shadow of the 12 digit gnomon is 13 aṅg 50 vyaṅgulus.

(i) 'First sine' = 1,72,800 ÷ (103′ 55″ × $\sqrt{13\ 14/15^2 + 144}$ = 1,72,800 ÷ (103′ 55″ × 18.389) = 90′ 26″.

(ii) Earth-sine = 60′ × 34′ 30″ ÷ 103′ 55″ = 19′ 55″

(iii) Sine I = (90′ 26″ − 19′ 55″) 240 ÷ 229′ 51″ = 73′ 38″

(iv) Sine II = 19′ 55″ × 240 ÷ 229′ 51″ = 20′ 48″

(v) Arc I = 38° 3′. Arc II = 9° 59′. The time from sunrise in *nāḍis* = $\frac{38°3'}{6} + \frac{9°59'}{6}$ = 8 *nāḍis*.

(Note that this work is the inverse of example 15 (a). There, 8 *nāḍis* were given, and the shadow 13 *aṅg* 56 *vyaṅg* was computed. Here, for the shadow 13 *aṅg* 56 *vyaṅg*, the *nāḍis* amounting to 8 have been computed).

Example 17 (b) For the same place, on the same day, find the time when the shadow is 137 aṅg 57 vyaṅg.

(i) 'First sine' = 1,72,800 ÷ (103′ 55″ × $\sqrt{144 + 137\ 57/60^2}$ = 12′ 1″.

(ii) Earth-sine = 60′ × 34′ 30″ ÷ 103′ 55″ = 19′ 55″.

(iii) Sine I = (12′ 1″ − 19′ 55″) × 240 ÷ 229′ 51″ = − 8′ 15″

(iv) Sine II = 19′ 55″ × 240 ÷ 229′ 51″ = 20′ 48″.

(v) Arc I = − 3° 57′, Arc II = 9° 59′. The time from sunrise = − 3° 57′/6 + 9° 59′/6 = 1 *nāḍi*. (Note that is the inverse of Example 15 (b). There the shadow 137 *aṅg* 57 *vyaṅg* was computed for one *nāḍi* from sunrise. Here for the same shadow the time one *nāḍi* is computed.)

We shall do the same by the inverse operation of the work previously given by the author: The 'First sine', computed is 12′ 1″. The Earth-sine computed is 19′ 55″, and greater than the 'First sine'. Therefore taking the 'First sine' alone, 12′ 1″ × 240 ÷ 229′ 51″ = 12′ 33″. The arc of this = 6° 2′. Dividing by 6, the time obtained is one *nāḍi* and 1/3 *vinādi*, and neglecting the negligible 1/3 *viṇāḍi*, we see the same time is got. For proof of the rules here given, we shall derive these from the rules for the shadow given the time, as the operation is practically the inverse of the operation given there. In the previous work, rule (ii) gives:

12 × $\sqrt{14{,}400 - \sin^2 \text{altitude}}$ ÷ sin altitude = shadow.
∴ 144 × (14,400 − $\sin^2$ alt.) = $\sin^2$ alt. = shadow^2.
∴ 144 × 14,400 = $\sin^2$ alt. × shadow^2 ± 144 $\sin^2$ alt. = $\sin^2$ alt. (shadow^2 + 144).
∴ 12 × 120 = sin alt. × $\sqrt{\text{shadow}^2 + 12^2}$.
∴ 12 × 120 ÷ $\sqrt{\text{shadow}^2 + 12^2}$
= sin alt. = 12 × 120 × 120 × sin colat. ÷ (120 × sin colat. × $\sqrt{\text{shadow}^2 + 12^2}$
= 'First sine' × sin colat. ÷ 120,
(because, 12 × 120 × 120 ÷ (sin colat × $\sqrt{\text{shadow}^2 + 12^2}$) = 1,71,800 ÷ (sin colat × $\sqrt{\text{shadow}^2 + 12^2}$)
= 'First sine' as given).

Similarly, in the previous rule (i),
sin alt. = {sine (degrees of time ∓ degrees of half-*cara*) ± sin half-*cara*} × sin colat. × day-diameter ÷ 28,800,
= 'First sine' × sin colat. ÷ 120.
∴ 'First sine' × 240 ÷ day-diameter = {sin (degrees of time ∓ degrees of half-*cara*) ± sin half-*cara*}.
∴ 'First sine' × 240 ÷ day-diameter ∓ sin half-*cara*
= sin (degrees of time ∓ degrees of half-*cara*).
∴ 'First sine' × 240 ÷ day-diameter ∓ Earth-sine × 240 ÷ day-diameter
= sin (degrees of time ∓ degrees of half-*cara*).
∴ ('First sine' ∓ earth-sine) × 240 ÷ day-diameter
= sin (degrees of time ∓ degrees of half-*cara*)
= sin (degrees of time after the Sun has touched the *unmaṇḍala*)

From the sin degrees of time, and thence by dividing by 6, the time in *nāḍis* after the Śun has touched the *unmaṇḍala* is obtained. The addition or subtraction of the half-*cara* to this gives the time from sunrise, to obtain which sin half-*cara* is got from the Earth-sine, and then its arc, *viz* the degrees of half-*cara*.

षड्घ्नेऽथ स्वद्युमिते छिन्ने सद्वादशैर्विमाध्याह्नैः ।
छायाङ्गुलैर्गतास्ता नाड्यः प्राक् पृष्ठतः शेषाः ॥ ४८ ॥

Time for sunset

48. Or roughly, multiply the duration of daytime in *nāḍis* by 6, and divide by the shadow increased by 12 and decreased by the midday shadow of date. The time from sunrise is got in the forenoon, and the time to elapse for sunset is obtained in the afternoon.

The shadows mentioned here are those of the twelve-digit gnomon and not the shadows of a person measured by his foot.

The rule is the time in *nāḍis* = 6 × daytime in *nāḍis* ÷ (shadow + 12 − mid-day shadow).

Example 18. Given the duration of daytime, nāḍis 33-20, and mid-day shadow, 2 aṅg 50 vyaṅg. Find the time when the gnomonic shadow is 13 aṅg 56 vyaṅg.

The time = 6 × 33 1/3 ÷ (13 14/15 + 12 − 2 5/6)
= 200 ÷ 23 1/10 = *nāḍis* 8-37.

The data given in the example are for the place and day in Example 16 (a), and we must get *nāḍis* 8, as the time. But we get *nāḍis* 8-37. From this we can have an idea of the roughness of this method. Evidently VM wants us to use this rule if we feel that this accuracy is sufficient, for, this is easy to use, provided the daytime and the midday shadow are tabulated beforehand and kept ready.

The rule may be explained in the manner we explained the similar rule with *Vāsiṣṭha Siddhānta*. Let us assume, time = x × day-time ÷ (shadow − mid-day shadow + y), where x and y are two constants to be determined. (The daytime occurs as a multiplier in the rule because, other things being equal, the time must vary with the daytime. For the deduction of the mid-day shadow from the shadow, see the explanation in the *Vāsiṣṭha*.) At noon the shadow is equal to the mid-day shadow of date, and the time is daytime/2. Therefore we have:
x × day time ÷ (mid-day shadow − mid-day shadow + y) = daytime/2.

∴ 2x × daytime = daytime × y.
∴ 2x = y.

Therefore, whatever be the multiplier for the daytime, twice that is the constant additive to the shadow, as in the author's rule here, 6 and 12, respectively. Only so far can we go in the explanation

48. Quoted by Utpala on *BS* 2, p.62
48a. A. षट्ह्योथवा द्युमाने; C.D. षड्घ्नेऽथवा द्युमाने
b. A. ०दशे विमध्याह्ने
c. A1. गतास्था; A2. गतास्थे
d. A. नाद्यः. A. प्रष्टतो

whether actually the constants are 6 and 12, as here or 5 and 10, or some other number and double that, depends upon the accuracy of the result we get.

For the matter of that there is another rule, very popular and attributed to our author himself in the following form:
time = 5 × daytime ÷ (shadow − mid-day shadow + 10), given by the popular verse:

chāyā nijeṣṭā dinamadhyabhāgacchāyonitā diksahitā tayāpte |
dine śaraghne gatagamyanāḍīḥ śrīmān Varāho vadati syayuktyā ||

Here too the shadow is that of the 12 digit gnomon. Note that the multiplier here is 5, and the additive constant double that, viz. 10. Actually, different constants for different places, and for different times, even if the place is the same, may have to be used if sufficient accuracy is to be secured. So the average for a particular region may be used for that region in the rough rule.

Let us now compute the constants using the data of *Example 16* (a), and examine the degree of accuracy of the constants 5 and 10 used in the above verse. In the example we find that the time is 8 *nāḍis* for shadow *aṅg* 13-56. The daytime for the day is *nā.* 33-20 and mid-day shadow, *aṅg.* 2-50, as we have already given in *Example 17.* Using the assumed form,

x × 33 1/3 ÷ (13 14/15 + 2x − 2 5/6) = 8.
x × 33 1/3 = 8 (2 x + 11 1/10) = 16 x + 88 4/5.
17 1/3 x = 88 4/5.
x = 88 4/5 ÷ 17 1/3 = 444 ×3 ÷ (5 × 52) = 5 8/65.

As 8/65 is small, x, the multiplier, may be taken as 5, and y (i.e. 2x) may be taken as 10, with tolerable accuracy, as VM himself seems to have done in the popular verse. Let us examine the accuracy given by this by working *Example 17* using this.

The time = 5 × 33 1/3 ÷ (13 14/15 + 10 − 2 5/6) = 500 × 10 ÷ (3 × 211)

=*nā.* 7-54. Note how near this is to the correct 8 *nāḍis,* and contrast with the result of the rule given by the text, *nā.* 8-37.

Let us once again examine the relative accuracy by computing the time sought in the example under IV. 41-44, from the shadow caused by the Sun on the prime vertical, at the place and time of *Example 16 (a).* The prime vertical shadow was given as *aṅg.* 17-4. The time got there was *nā.* 6-53. Using the rule of the text, time = 6 × 33 1/3 ÷ (17 1/15 − 2 5/6 + 12) = *nā.* 7-37, which is far from the correct *nā.* 6-53.

Using the popular verse,
time = 5 × 33 1/3 ÷ (17 1/15 − 2 5/6 + 10) = *nā.* 6-53, agreeing exactly with the correct time. What are we to conclude from this?

[नाडीतः छाया]

छायाऽर्कौ नाडीभिर्दिनमानं षड्घ्नमुद्धरेत्तत्र |
लब्धं द्वादशहीनं मध्याह्नच्छायया सहितम् || ४९ ||

Shadow from time

49. Roughly again, the shadow can be got thus from the time: Multiply the daytime by 6, and divide by the time for which the shadow is sought. Add the

mid-day shadow to the result and deduct 12. The shadow of the gnomon, caused by the Sun, is got.

This means: Shadow at any time $=6 \times$ daytime $\div$ the time taken + midday shadow $-$ 12.

Example 19. Given daytime = nā. 33-20, mid-day shadow = aṅg. 2-50, find the shadow at *nā.* 8-0 from sunrise.

Shadow $= 6 \times 33\ 1/3 \div 8 + 2\ 5/6 - 12$
$= 25 + 2\ 5/6 - 12 =$ *aṅg.* 15-50.

(Actually the shadow is *aṅg.* 13-56, which can be seen from the previous examples).

But if the constants in the popular verse, 5 and 10, are used, then the rule becomes,
Shadow $= 5 \times$ daytime $\div$ taken time + mid-day shadow $-$ 10.

Using this, the shadow $= 5 \times 33\ 1/3 \div 8 + 2\ 5/6 - 10 = 20\ 5/6 + 2\ 5/6 - 10 =$ *aṅg.* 13-40.

See how close this is to the correct, 13-56.

Being the inverse of the operation of finding the time from the shadow, this rule can be derived from the previous rule, *viz,* $6 \times$ daytime $\div$ (shadow $-$ mid-day shadow + 12) = time in *nāḍis.*

$\therefore$ 6 x daytime $\div$ time = shadow $-$ mid-day shadow + 12.

$\therefore$ shadow = 6 x daytime $\div$ time + mid-day shadow $-$ 12, which is the present rule.

[चन्द्रच्छाया]

(इ)ष्टा नाड्यो द्युनिशं चन्द्रोदयनाडि[का]युतविही(नाः) ।
ताभिस्तत्कालेन्दोर्भानोरिव चिन्तये(च्छा)याम् ॥ ५० ॥

Moon's shadow

50. To compute the Moon's shadow at any time in the night, the time after sunset is to be added to the *nāḍis* from moonrise to sunset if the Moon rises in the day. If the Moon rises after sunset, the time of moonrise after sunset is to be subtracted from the taken time. This is to be used as the time taken for computation, and work done as in the case of the Sun to get the Moon's shadow.

The work is to be done thus: Upto the desired time after sunset, the time after moonrise is to be found, and this time is to take the place of the time after sunrise in the work of finding the shadow as in IV. 41-44. So, for the desired time the Moon's true declination and day-diameter have to be found and these are to be used in the place of the Sun's declination and day-diameter. The required *cara* etc. are to be found using these. As the *nāḍis* pertain to the solar day, they should be made lunar and used. The two examples given hereunder will make the work clear. The author's intention is

49. Quoted by Utpala on *BS* 2, p.62

49a. A.नाडिभि
b. A.षट्समु. A1.द्धरेतत्र; A2.द्धरेत्तत्र

50a. A.C.D.दृष्टा. A.द्युनिशे
b. A.नाडियुत. A1.विहीना; A2.विहिना
c. A.कालंदो
d. A.छायां

to convey that the inverse process of finding the time from the Moon's shadow is also to be done as from the Sun's. The time of moonrise required in this work will be given by the author in V. 8-10. The Moon's true declination has been given already in IV. 16. The proof of the work is similar to that of the Sun's. It must be remembered that in getting the time from the Moon's shadow, successive approximation has to be done, as in the case of the sun, for the same reason.

The following should also be noted. If the desired time after sunset for which the shadow is sought is less than the time of moonrise after sunset, the work need not be done. Or if the moon sets in the night before the desired time, the work need not be done. Obviously, these should be examined before commencing the work. Much has to be said here, for which the reader is referred to works like the *Siddhānta Śiromaṇi.*

Example 20. The sine of latitude of a place is 45′ 56″, and thence the sine of colatitude 110′ 52″. There, on a particular day the daytime is nā. 32-24. The moonrise is at nā. 27-18 after sunrise. At that time the Moon's true declination is 15° south. (i.e. the Moon is in the southern hemisphere). Since Moon's declination is 31′ 4″, and thence the day-diameter 231′ 50″. The cara-vināḍis from these for the day is 132. The lunar day, i.e. the duration of moonrise to moonrise is 62 nāḍis. Compute the shadow caused by the Moon at nā, 4-8 after sunset.

The time to be taken for computation = the time from moonrise to the given time

= the time from moonrise to sunset +the given time (after sunset)
= *nā*. 32-24 − *nā*. 27-18 + 4-8
= *nā*. 9-14.
The Moon's *cara-vināḍis* = 132, given.

Both should be converted to the lunar measure.

For 62 *nāḍis* there is one lunar day, i.e. 60 lunar *nāḍis;* so for *nā*. 9-14, there are 9-14 × 60/62 = 8-56 lunar *nāḍis.*

Converting into degrees, we have (8-56) × 6 = 53° 36′.

Similarly, the *cara-vināḍis* made lunar = 132 × 60/62 = 128.

Converted into degrees, 128/20 = 6° 24′.

Now, using the rules of verses 40-44,

(i) Sin altitude = {sin (53° 36′ + 6° 24′) − sin 6° 24′)} × 231′ 50″ × 110′ 52″ ÷ 28,800 (the upper sign is taken because the Moon is in the southern hemisphere).

= (sin 60° − sin 6° 24′) × 231′ 50″ × 110′ 52″ ÷ 28,800
= (103′ 55″ − 13′ 23″) 231′ 50″ × 110′ 52″ ÷ 28,800
= 90′ 32″ × 231′ 50″ × 110′ 52″ ÷ 28,800
= 80′ 49″.

(ii) gnomonic shadow caused by the Moon = $12\sqrt{14{,}400 - 80'\,49''^2} \div 80'\,49''$ = *aṅg*. 13, *vyaṅg* 11.

Example 21. For the same place and the same time of Example 20, find the time, given the shadow caused by the Moon is aṅg. 13-11, extending the method of verse 45-47 to the Moon.

The required elements already given in Example 20 are: sin lat. 45′ 56″, sin colat. 110′ 52″, sin Moon's declination 31′ 4″, sin Moon's day-diameter 231′ 50″, time of moonrise *nā*. 27-18 after sunrise, duration of the day *nā*. 32-24, and the duration of the lunar day = 62 *nāḍis.*

(i) 'First sine' = 1,72,800 ÷ (110′ 52″ × $\sqrt{13\ 11/60 + 12^2}$) = 87′ 26″.

(ii) Earth-sine = 45′ 56″ × 31′ 4″ ÷ 110′ 52″ = 12′ 52″

(iii) Sine I = (87′ 26″ + 12′ 52″) × 240 ÷ 231′ 50″ = 103′ 55″, (since the Moon is in the southern hemisphere).

(iv) Sine II = 12′ 52″ × 240′ ÷ 231′ 50″ = 13′ 23″.

(v) Arc sine I = 60°. Arc sin II = 6° 24′. The time of shadow after moonrise = (60° − 6° 24′)/6 = 53° 36′/6 = *nā*. 8-56, (Moon being in the southern hemisphere).

This time pertains to the lunar *sāvana* day, and converted into ordinary (i.e. solar) *sāvana*, the time after moonrise = 8-56 × 62 ÷ 60 = *nā*. 9-14.

The time from sunrise = *nā*. 27-18 + *nā*. 9-14 = *nā*. 36-32.

The time from sunset = *nā*. 36-32 − *nā*. 32-24 = *nā*. 4-8.

The result is correct, because in *Example 20*, we took this same time and got the shadow *aṅg*. 13-11, which we have used in this example.

चरनाडीक्रमविधिना द्युव्यासा (द्य) थामति [च] विक्षे (पात्)
अस्तमयोऽप्यध्वविधिः शेषाणां युक्तितश्चिन्त्यम् || ५१ ||

51. For the others, (i.e. for the luminaries other than the Sun and the Moon, viz. the star-planets) also, determining the corresponding operations, and using their respective latitude and day-diameter, and getting the *cara-nāḍis* etc. (in terms of their respective *sāvana* days), (not only the work of finding the shadow for the given time and time for the given shadow as above, but also) their daily risings and settings and reduction to different localities should be thought out and done.

The following is the idea. The computation of the rising and setting of the Sun has been given already in this chapter. The Moon's rising and setting will be given below, in chapter V. Understanding the nature of the operation from these and taking the star-planets corrected to the different longitudes and computing their respective *sāvana* days and *cara-vināḍis*, using their latitudes to get their true declinations and day-diameters, everything done in connection with the Sun and the Moon should be done in connection with the star-planets also.

It is from this that we understand that in the work of computing the Moon's shadow we have to use the true declination, day-diameter, and time measured in the Moon's *sāvana* day, as we have done already. Therefore this verse may also be taken as an extension of the previous verse.

Here TS and NP have done a lot of emendations that are unnecessary for, without those emendations we get the same idea as they have given, at such pains.

51a. D. चरनाड्य [प] क्रमा [दि] विधिना A.C.D. om च. A.D. विक्षेपम्; C. विज्ञेयम्
b. A. द्युव्यासान्यभाति; C. द्युव्यासापक्रमादि; D. द्युव्यासापक्रम
c. C. मये पूर्व विधिः; D. मयेऽप्यूर्ध्वविधिः

[छायातः दिक्साधनम्]

छाया'ऽर्क'वर्गयोगा(त्पदेन) भाज्यार्कसंगुणा त्रिज्या ।
विषुवज्जीवागुणिता (लम्बक) भक्ता तु सूर्याग्रा ॥ ५२ ॥
का(ष्ठ)घ्नयार्कमौर्व्या लम्बकहृतया वि(हीन)संयुक्ता ।
सूर्याग्रा(ऽज)तुलादौ कर्णघ्नी त्रिज्ययाऽपहृता ॥ ५३ ॥
लब्धाङ्गुलानि (को)टिस्त(च्छा)यावर्गविवरमूलं [यत्] ।
स च (बाहुर्दिग्ग्र)हणे सममि(तिः) को(ट्या) तु देयमृजु ॥ ५४ ॥

Directions from shadow

52. Twelve times the radius (i.e. 1440) is to be divided by the 'Shadow-hypotenuse', i.e. the root of the sum of the squares of the shadow and 12. This multiplied by sine latitude and divided by sin co-latitude and divided by sin co-latitude is called *Sūryāgrā* (otherwise well-known as *Śaṅkvagram* or *Śaṅkutalam*).

53. From this *Sūryāgrā*, the sine of the Sun's declination divided by the sine of co-latitude (which is otherwise called *Agrā*) should be deducted or added, according as the Sun is in the six signs beginning with Aries, or the six signs beginning with Libra, (i.e. according as the declination is north or south). The result is to be multiplied by the 'Shadow-hypotenuse' and divided by the radius, (i.e. by 120).

54. What is obtained are termed *Koṭi*, (or 'Perpendicular'), measured in digits. The root of the square of the *Koṭi* deducted from the square of the shadow is called *Bāhu* (or 'Base'.) and the *Koṭi* is to be so constructed as to be perpendicular to the 'Base', (whose extension both ways is the prime vertical). Thus the directions are got.

The following are the steps in the work:

(i) Shadow hypotenuse = $\sqrt{\text{shadow}^2 + 144}$

(ii) *Sūryāgrā* 12 × 120 × sin latitude ÷ (shadow hypotenuse × sin colat.)

(iii) *Agrā* or Amplitude = sin max. dec. of Sun × sin Sun's long. ÷ sin colat. = sin dec. of Sun × 120 ÷ sin colat. (The declination is north if the Sun is in the six signs from Aries, and south otherwise)

52a-b. A.C.D. योगा (C.D. योगात्) पदे विभाज्यार्क
b. D. संगु(णिता] त्रिज्या ।
d. A. लङ्काभक्ता
53a. A. काष्टेयार्क; C.D. काष्ठाहतार्क
b. A. विहितसंयुक्ता
c. A. ०ग्रा च तुलादौ
54a. A. काटि
b. A. तछाया. A. om यत्
c. A1. वाद्गदि ग्रहणे; A2. बाहुदिग्रहणे
d. A. मितिक्रोद्यातु देयमृणं. C.D. सममिति

(iv) (*Sūryāgrā* ∓ *Agrā* × shadow hyp. ÷ 120 = 'Perpendicular' (of ∓, the upper sign is for north declination, and the lower for south. If the 'Perpendicular' got is positive then it is north, if negative, south.)

(v) $\sqrt{\text{shadow}^2 - \text{Perpendicular}^2}$ = Base

Here, steps (ii), (iii) and (iv) can be simplified and put in the form: 'Perpendicular' = (12 × sine latitude ∓ shadow hypotenuse × sin declination) ÷ sin colat. (of ∓, the upper sign is for north declination and the lower for south. As already said, the Perpendicular obtained is north if positive and south if negative. If, when the declination is north. Shadow hypotenuse × sin declination > 12 × sin latitude, then deduct the less from the greater and take it as negative, i.e. take the resulting Perpendicular as south.)

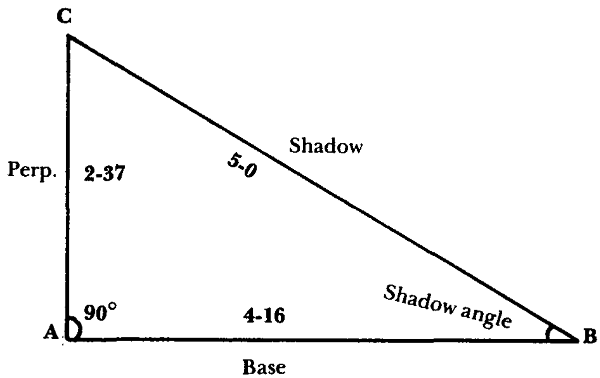


Fig. IV. 15

Example 22. The latitude of a place is 30°, whence sin lat = 60′, and sin colat = 103′ 55″. The Sun at the time of taking the shadow = rāśi 1-15, whence sin Sun's long = 84′ 51″, sin declination = 48′ 48″ × 84′ 51″, ÷ 120 = 34′ 30″, (north, as the Sun is in the first 6 signs). For this place and time if the shadow is 5 digits, find the direction of the shadow.

(i) shadow hypotenuse = $\sqrt{5^2 + 144}$ = 13.

(ii) *Sūryāgrā* = 12 × 120 × 60 ÷ (13 × 103′ 55″) = 63′ 57″.2

(iii) Agrā = 48′ 48″ × 84′ 51″ ÷ 103′ 55″ = 34′ 30″ × 120 ÷ 103′ 55″ = 39′ 51″.4

(iv) 'Perpendicular' = (63′ 57″ − 39′ 51″) × 13 ÷ 120 = *aṅg.* 2-36.6

(The 'Perpendicular' is north, as the result is positive)

(v) The 'Base' = $\sqrt{5^2 - (2 - 36.6)^2}$ = *aṅg.* 4-16.

Or, using the simplified form, the Shadow-hypotenuse, 13 *aṅg*, being known, 'Perpendicular' = (12 × 60′ − 13 × 34′ 30″) ÷ 103′ 55″ = 271′ 30″ ÷ 103′ 55″ = *aṅg.* 2-36.6. Then the 'Base' is calculated as done above.

Using the 'Base' and the 'Perpendicular', the direction of the shadow is found thus graphically. (see Fig. 15).

Here AB is the 'Base' which, extended on both sides, is the prime vertical. AC is the 'Perpendicular', extending northwards from AB that lies east-west. Angle CAB = 90°. BC is the shadow, and angle ABC is the angle made by the shadow with the east-west line. The direction of the sun is the line CB extended backwards, making the same angle with AB extended.

Example 23. For the same place and the same day, find the Sun's direction, when the shadow is aṅg. 27-30.

(i) Shadow hypotenuse = $\sqrt{27\frac{1}{2}^2 + 144}$ = *aṅg.* 30

(ii) *Sūryāgrā* = 12 × 120 × 60 ÷ (30 × 103′ 55″) = 27′ 42″.8

(iii) *Agrā* = 39′ 51″.4, found in example 22.

(iv) 'Perpendicular' = (27′ 42″.8 − 39′ 51″.4) × 30 ÷ 120

= *aṅg.* − 3-2, i.e. *aṅg.* 3-2 southward. (Or, which is the same, deducting 27′ 42″.8 from 39′ 51″.4, and doing the work with the remainder 12′ 8″.6, the perpendicular obtained is *aṅg.* 3-2, negative and ∴ southward).

(v) 'Base' = $\sqrt{27\frac{1}{2}^2 - 3\ 1/30^2}$ = *aṅg.* 27-20.

Or, by the simplified formula,

'Perpendicular' = (12 × 60′ − 30 × 34′ 30″) ÷ 103′ 55″ = (720′ − 1035′) ÷ 103′ 55″ = −315′ ÷ 103′ 55″

= *aṅg.* 3-2 southward.

From the 'Perpendicular' the 'Base' is found as already done.

The direction of the shadow is found graphically thus:

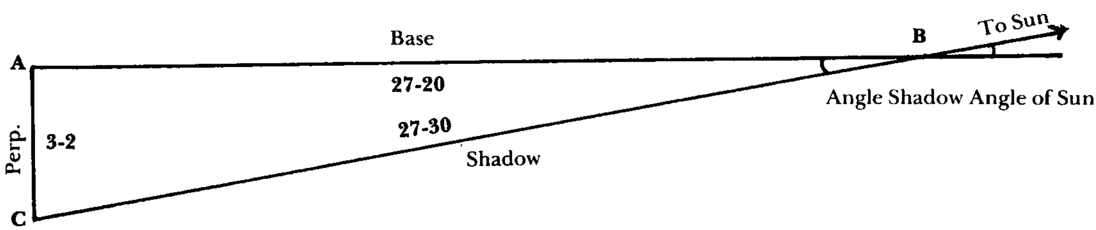


Fig. IV. 16

Here, AB is the 'Base', which extended both ways, is the prime vertical. AC is the Perpendicular, directed southwards. BC is the shadow. Angle ABC is the direction of shadow. At an equal angle to the east-west on the opposite side is the Sun.

Example 24. Sin lat of place = 72′, whence sin colat = 96′. The longitude of the Sun = rāsi. 11-0, from which sin longitude of the Sun = 60′, and thence sin decl = 24′ 24″, south, since the Sun is within the six signs from Libra. Find the direction when the shadow is aṅg. 27-30.

(i) Shadow-hypotenuse = $\sqrt{144 + 27\frac{1}{2}^2}$ = *aṅg.* 30.

(ii) *Sūryāgrā* = 12 × 120 × 72′ ÷ (96 × 30) = 36′.

(iii) *Agrā* = 48′ 48″ × 60 ÷ 96′ = 30′ 30″.

(iv) The Sun being in the six signs from Libra, 'Perpendicular' = (36′ + 30′ 30″) × 30 ÷ 120′ = *aṅg*. 16-37.5 north.

(v) 'Base' = $\sqrt{27\frac{1}{2}^2 - 16\frac{5}{8}^2}$ = *aṅg*. 21-54.

Or by the simplified formula,

Perpendicular = (12 × 72′ + 30 × 24′ 24″)/96 = *aṅg*. 16-37.5. (+ is taken, as the declination is south).

From this the 'Base' is calculated to be *aṅg*. 21-54 as before.

The direction is graphically represented thus:

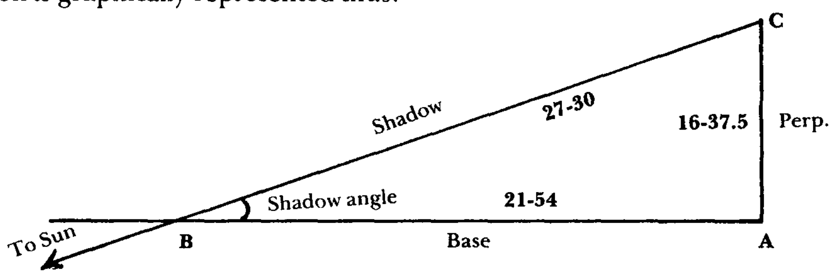


Fig. IV. 17

Here too, the angle of shadow is ABC, and the direction of the Sun is opposite to the shadow, making the same angle.

We shall now prove the steps, taking them one by one:

(i) Shadow-Hypotenuse: In the right angled triangle having the shadow as base and the twelve digit gnomon as perpendicular, the shadow-hypotenuse is the hypotenuse. Hence by the well-known formula, base^2 + perpendicular^2 = hypotenuse^2, $\sqrt{\text{shadow}^2 + \text{gnomon}^2}$ = shadow-hypotenuse. As the gnomon is 12 *aṅgulas* and the shadow too is measured in *aṅgulas*, the shadow-hypotenuse measured in *aṅgulas* = $\sqrt{\text{shadow}^2 + 12^2}$.

(ii) Sūryāgrā: This is the distance between the line joining the rising and setting points and the diurnal circle (see Fig. 18). This is called *śaṅkvagra* by the earlier Bhāskara I and his followers and *śaṅkutalam* by the later Bhāskara II and others.

It has been mentioned that, as seen from places on the earth other than the equator, since the circles on the stellar sphere are bent southwards (this is from the point of view of people in the northern hemisphere) the diurnal circles following these are also bent southwards. Therefore by the intersection of the arcs on the stellar sphere and the celestial sphere several right angled triangles are formed by their sine lengths, which triangles are called 'Latitude-caused triangles' (*Akṣakṣetras*). From the similarity of these triangles, when the length elements of one are known the corresponding length elements of another may be calculated by the rule of proportion. Among these, two similar triangles answer to our need, in one, which is well-known, sin lat is the base, sin colat is the perpendicular, and

the radius is the hypotenuse; and in the other *Sūryāgrā* (i.e. *śaṅkutalam*) is the base, the Great gnomon is the perpendicular and what is called *Taddhṛti* is the hypotenuse (Vide *Sid. Śiromaṇi, Gola, Tripraśna* 49). Therefore, when sin lat, sin colat, and the Great gnomon are known *Sūryāgrā* can be calculated by the proportion:

Sin colat: sin lat :: Great gnomon: *Sūryāgrā*.

Sūryāgrā = Great gnomon × sin lat ÷ sin colat.

The Great gnomon can be found from the similarity of the two triangles, in one of which the shadow is the base, the twelve-digit gnomon is the perpendicular and the shadow-hypotenuse is the hypotenuse, and in the other sin zenith distance is the base, the Great gnomon is the perpendicular, and the radius is the hypotenuse.

Therefore by the proportion: shadow-hypotenuse : 12 :: radius : Great gnomon, the Great gnomon = 12 ×120′ ÷ shadow-hypotenuse.

Hence by substituting we get, *Sūryāgrā* = 12 × 120′ × sin lat ÷ (shadow-hypotenuse × sin colat). Since the celestial sphere is bent southward, *Sūryāgrā* is really south, permanently, (from the point of view of a man in the northern hemisphere, as we have already said). But here, as we are dealing not with the Sun but with the shadow, which is opposite to the Sun, we have taken the *Sūryāgrā* as always north. We shall illustrate these things by Fig. 18.

We have mentioned that for observers in the northern hemisphere the diurnal circles bend southward, resulting in the 'southing' of the celestial bodies, because of the southward bend of the stellar sphere. As the shadow moves in the direction opposite to the Sun, the tip of the shadow moves in circles bent northwards, like I, II, III, in the Fig. Also, it should be remembered, as we are depicting the shadows in the Fig, the direction of *Agrā* and *Sūryāgrā* are reversed.

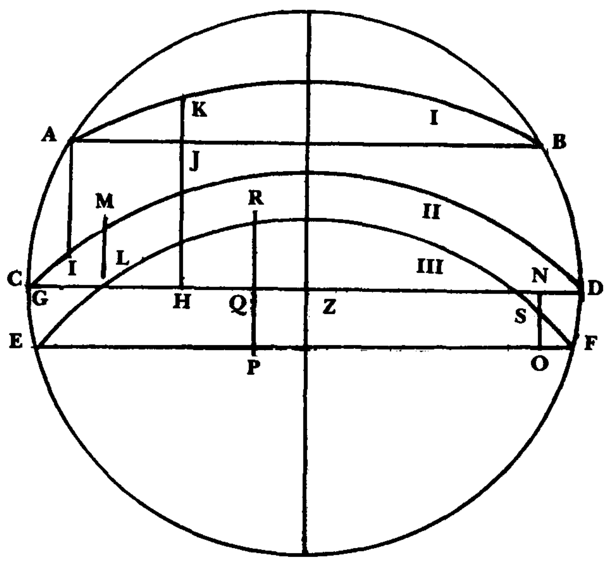


Fig. IV. 18.

I: The circle on which the tip of the shadow moves on a day when the Sun is in the southern hemisphere.
II: The circle on which the tip of the shadow moves on a day when the Sun is on the equator.
III: The circle on which the tip of the shadow moves on a day when the Sun is in the northern hemisphere.

A, B = rising and setting points of the Sun, on the day related to I.

C, D = rising and setting points of the Sun on the day related to II, and E, F, related to III.

AB, CD, and EF are the lines joining the respective rising and setting points and are parallel to one another.

With reference to I, (i.e. for a day when the Sun is in the southern hemisphere), GA = HJ = *Agrā* (directed northward), JK = *Sūryāgrā* (directed northward) and HK = *Agrā* + *Sūryāgrā*, from which it is obvious that the Perpendicular is also directed northward.

With reference to II, (i.e. for a day when the Sun is on the equator), the Sun rises at C itself and sets at D itself, and therefore the *Agrā* is zero. LM is the *Sūryāgrā* (directed northward) and the 'Perpendicular' = *Sūryāgrā* ∓ *Agrā*, is also LM.

With reference to III, (i.e. for a day when the Sun is in the northern hemisphere), *Agrā* = QP = NO (directed southward) and PR or OS is the *Sūryāgrā* (directed north). At a time sufficiently near sunrise or sunset, for which OS is the *Sūryāgrā*, the Perpendicular is NS (directed southward). This is the case where *Agrā* is deductive but numerically greater than the *Sūryāgrā*. At a time sufficiently near noon, for which PR is the *Sūryāgrā*, the Perpendicular is QR got by PR − PQ, QP being numerically less than PR.

(iii) Agrā: This is the amplitude, and forms the distance between the parallel lines constituting the prime vertical and the line joining the rising and setting points. This is also the sine of the angles of the rising and setting points made from the East or West points, respectively. The author has given the formula for this in V. 39, without mentioning its name *Agrā*, as also here without mentioning its name. The derivation of the formula has been given by us there. When the Sun is in the northern hemisphere, this is north, and when in the southern, it is south. But here, as we are dealing with the shadow, we have reversed the directions.

One thing must be mentioned in this connection: TS and NP interpret the word *Sūryāgrā* as *Agrā* or 'Sine of the amplitude of the Sun', evidently assuming the derivation *sūryasya agrā* = Sūryāgrā, i.e. *Agrā* itself, because the context is the Sun here. As for *Sūryāgrā* itself, they simply call it 'a sine'. They have failed to notice that if taken thus, the formula for getting them would become wrong. Even if somehow, by changing the order of words in the sentence, we make the formulae agree in this work, in the next work of getting the sun from the direction of the shadow, it would be impossible to secure agreement between the words there. But we must mention here that in the *Mahābhāskarīya*, *Agrā* is termed '*Arkāgrā*', evidently by the derivation, *arkasya agrā arkāgrā*. *Sūryāgrā* is there called *Śaṅkvagra*, as we have already said. (*Vide Mahābhāskarīya*, III. 53-54). But here we have no choice except to go by the text.

(iv) Perpendicular: From what we have already said, and from the Fig. 18, it can readily be seen that (*Sūryāgrā* ∓ *Agrā*) is the distance between the Prime vertical and the tip of the Great shadow. This is called '*Bhuja*' by other authors. The *Bhuja* corresponding to the shadow is got from this by the proportion,

Radius: *'Bhuja'* :: shadow-hypotenuse : shadow-*Bhuja*, So we have,

(*Sūryāgrā* ± Agrā) × shadow-hypotenuse ÷ 120 = shadow *Bhuja*.

Our author calls this *Koṭi* or 'Perpendicular', as we have already said. But this does not matter, for in a right angled triangle, with the hypotenuse given (as here the shadow), the other two sides are perpendicular to each other, and any one may be taken as the base, and the other as the perpendicular.

(v) Base: When the 'Perpendicular' is got from the well-known formula of the right angled triangle, $\text{Base}^2 + \text{Perpendicular}^2 = \text{hypotenuse}^2$, (the shadow being the hypotenuse here,) we have, $\text{'Base'} = \sqrt{\text{shadow}^2 - \text{Perpendicular}^2}$. Since the Perpendicular is north-south, the 'Base' is east-west, and is a part of the east-west line, as the foot of the shadow is on the east-west line. Since the east-west line is known, we can lay the 'Base' on it, lay the 'Perpendicular', at right angle, and draw the shadow. Clearly, if initially we have the shadow marked on the ground, we can get the directions by using this method. The angle between the shadow and the base gives the direction of the shadow. Obviously the direction of the Sun is given by the equal angle vertically opposite.

What has been said here for the shadow may be said for the sun without reversing the direction as we have done for the sake of the shadow, and the Sun's direction can be got. From that the direction of the shadow may be got as being vertically opposite. But it is clear that the author says everything here for the shadow, and not for the Sun.

[छायातः रव्यानयनम्]

छायासमरेखान्तरगुणिता त्रिज्या स्वकर्णभक्ताऽस्याः |
एकत्वे (विश्ले)ष्या सूर्याग्रा संयुताऽन्यत्वे || ५५ ||
लम्ब[क]गुणिता (भा)ज्या काष्ठामौर्व्या (ततो)ऽर्कः स्यात् |
सूर्योद्भवेन विधिना ग्रहा(स्त)तोऽन्येऽपि कर्तव्याः || ५६ ||

Sun from Shadow

55. (Explanatory translation): By a process reverse to the previous one, the longitude of the Sun can be computed from the shadow, thus: Take the distance of the tip of the shadow in *aṅgulas,* from the east-west line, multiply it by 120′ , and divide by the *aṅgulas* of the shadow hypotenuse (mentioned in the previous work). This is 'the sine'. (It may be seen that this is the *Sūryāgrā* ∓ Agrā, of the previous work). If the shadow is north of the east-west line then 'the sine' also is north. If the shadow is south, 'the sine' is south. Compute the *Sūryāgrā* as given already in the previous work. This is to be taken as always north (as already mentioned). If 'the sine' and *Sūryāgrā* are of different directions, then 'the sine' plus *Sūryāgrā* is *Agrā*. (It must be remembered that they will be of different directions only when the Sun is in the northern hemisphere, i.e. within the six signs from Aries). If they are of the same direction, then the *Agrā* is one deducted from the other. (If 'the sine' is greater, then the Sun is in the southern hemisphere, i.e. within the six signs from Libra. If

Sūryāgrā is greater, then the Sun is in the northern hemisphere, i.e. in the six signs from Aries).

56. The *Agrā* thus got multiplied by the sine of colatitude, and divided by 48′ 48″. is the sine of the Sun's longitude and from that the sun is obtained. (From this sine, first the degrees of *Bhuja*, D, is got. If the Sun is in the northern hemisphere, then the Sun's longitude is D, or (six signs − D). If the Sun is in southern hemisphere, the Sun's longitude is six signs + D, or (twelve signs − D). What exactly it is of the diad must be determined by the Sun's *ayana*). (Following the method for the Sun, the other *grahas* also can be got).

The following are the steps in the work:-

(i) As already seen, shadow-hypotenuse = $\sqrt{\text{shadow}^2 + 144}$.

(ii) As already seen, *Sūryāgrā* = 12 × 120 × sin lat ÷ (shadow-hypotenuse × sin colat).

(iii) 'The sine' = the distance in *aṅgulas* from the east-west line to the tip of the shadow × 120′ ÷ shadow-hypotenuse. (If the shadow is north of the east-west line, 'the sine' is north, if the shadow is south of the east-west line, 'the sine' is south).

(iv) (a) If 'the sine' is north, and greater than the *Sūryāgrā*, *Agrā* = 'the sine' − *Sūryagrā*, and the Sun is in the southern hemisphere.

(b) If 'the sine' is north and less than the *Sūryāgrā*, *Agrā* = Sūryāgrā — 'the sine', and the Sun is in the northern hemisphere.

(c) If 'the sine' is south, *Agrā* = Sūryāgrā + 'the sine', and the Sun is in the northern hemisphere.

(v) Sine longitude of the Sun = *Agrā* × sin colat ÷ 48′ 48″ = *Agrā* × sin colat × 5 ÷ 244.

(vi) From the sine of longitude, the *Bhuja* degrees D, and using that the longitude of the Sun by examination, are to be obtained.

As in the previous work, (iii), (iv) and (v) can be simplified thus: Sine sun's longitude = (12 ×sin lat ± sin colat × the distance in *aṅgulas* between the tip of the shadow and the east-west line) × 150 ÷ (61 × shadow hypotenuse). In ± if the shadow is south of the east-west line then the upper sign is to be taken, and the Sun then is in the northern hemisphere. If the shadow is north, the lower sign is to be taken. In this case, if 12 × sin lat is greater, the Sun is in the northern hemisphere, and if sin colat × distance in *aṅgulas*, is greater, the sun is in the southern hemisphere.

Example 25. Of a certain place, sin lat = 60′, sin colat = 103′ 55″. There, on a day during Uttarāyāṇā, when the length of the shadow is 5 aṅgulas, the distance of the shadow tip from the east-west line is measured to be aṅg. 1-36.6, north of the east-west line. Find the longitude of the Sun.

(i) Shadow-hypotenuse = $\sqrt{5^2 + 144} = 13$ *aṅg.*

55a. A1.०त्वे तितेष्या; A2.०त्वे तिरतेष्या; A.D. सा ज्या
D.०त्वेऽन्तरितैष्या
b. A. काष्टा. A. मनोर्कः; D. हृतार्कः
c. A2. सूर्यो-वेन
d. A. सूर्यग्रा. A2. न्यवे
56a. A. लम्बगुणिता
d. A. ग्रहाश्चतो

(ii) *Sūryāgrā* = $12 \times 120' \times 60' \div (13 \times 103'\ 55'') = 63'\ 57''.2$

(iii) 'The Sine' = *aṅg*. 2-36.6 × 120 ÷ 13 *aṅg* = 24′ 6″. (This is north as shadow is north).

(iv) As 'the sine' is north, the lower sign is to be used, i.e. the difference is to be found. There, as *Sūryāgrā* is greater, *Agrā* = $63'\ 57''.2 - 24'\ 6'' = 39'\ 51''$ (The Sun is in the northern hemisphere).

(v) The sine of Sun's longitude = $39'\ 51'' \times 103'\ 55'' \times 5 \div 244 = 84'\ 51''$.

(vi) The *Bhuja* degrees D = Arc of 84′ 51″ = *rāśi*. 1-15. As the sun is in the northern hemisphere, the longitude is *rāśi* 1-15, or *rāśi* 6-0 — *rāśi* 1-15, i.e. *rāśi* 4-15. As the Sun is in *Uttarāyaṇa*, the longitude of the sun is *rāśi* 1-15.

Using the simplified method, and taking the lower sign since the distance is north,

sin Sun's long = (12 *aṅg* × 60′ ~ *aṅg* 2-36.6 × 103′ 55″) × 150 ÷ (61 × 13 *aṅg.)*

= $(720' - 271'\ 30'') \times 150 \div (61 \times 13)$

= 84′ 51″. (As 12 × sin lat is greater, the sun is in the northern hemisphere). The rest of the work is the same.

Example 26. Of a certain place, sin lat = 60′, sin colat = 103′ 55″. On a Dakṣiṇāyana day, when the shadow is aṅg. 27-30, its tip is found to be aṅg 3-2.15 south of the east-west line. Find the Sun.

(i) Shadow-hypotenuse = $\sqrt{144 + 27\frac{1}{2}^2}$ = *aṅg*. 30.

(ii) *Sūryāgrā* = $12 \times 120' \times 60' \div (30 \times 103'\ 55'') = 27'\ 42''.8$.

(iii) 'The sine' = *aṅg*. 3-2.15 × 120 ÷ *aṅg*. 30 = 12′ 8″.6 (south, as the shadow is south).

(iv) As the sine is south, the upper sign is to be taken, and the Sun is in the northern hemisphere, and therefore, *Agrā* = $27'\ 42''.8 + 12'\ 8''.6 = 39'\ 51''$.

(v) Sin longitude of Sun = $39'\ 51'' \times 103'\ 55'' \times 5 \div 244' = 84'\ 51''$.

(vi) The degrees of *Bhuja* = Arc 84′ 51″ = *rāśi* 1-15

As the Sun is in the northern hemisphere, the longitude is *rāśi* 1-15 or *rāśi* 4-15. As it is *Dakṣiṇāyana*, the Sun is *rāśi* 4-15.

Applying the simplified method for this, as the upper sign is to be taken, since the shadow tip lies south of the east-west line,

sin long = $(12 \times 60 + 103'\ 55'' \times 3.2) \times 150 \div (61 \times 30) = 84'\ 51''$, and the Sun must be in the northern hemisphere.

The rest of the work is the same as done already.

Example 27. Of a certain place sin lat = 72′, and sin colat = 96′. There, on a certain day in Uttarāyaṇa, when the shadow is aṅg. 27-30, the distance of its tip from the east-west line is aṅg. 16-37.5 north. Find the Sun.

(i) Shadow hypotenuse = $\sqrt{144 + 27\frac{1}{2}^2} = 30$.

(ii) *Sūryāgrā* = $12 \times 120' \times 72' \div (30 \times 96) = 36'$.

(iii) 'The sine' = *aṅg*. 16-37.5 × 120 ÷ *aṅg*. 30 = 66′ 30″, (north, as the distance is north).

(iv) As 'the sine' is north, the difference is to be taken. As 'the sine' is greater, *Agrā* = 66′ 30″ − 36′ = 30′ 30″, (and the Sun is in the southern hemisphere).

(v) Sine latitude of Sun = 30′ 30″ × 96 × 5 ÷ 244 = 60′.

(vi) The degrees of *Bhuja* = *rāśi* 1-0. As the Sun is in the southern hemisphere, the Sun is *rāśi* 6-0 + *rāśi* 1-0, i.e. *rāśi* 7, or *rāśi* 12-0 − *rāśi* 1-0, i.e. *rāśi* 11. As it is *Uttarāyaṇa,* the Sun's longitude must be *rā.*11.

Applying the simplified method, since the lower sign is to taken as the distance is north, sin long = (12 × 72 ∼ 96 × 16-37.5) × 150 ÷ (61 × 30).

Here since distance × sin colat is greater,

Sin long = (96 × 16-37.5 − 12 × 72) × 150 ÷ (61 × 30) = 60′, and the Sun must be in the southern hemisphere.

The rest of the work is the same.

The proof of the above rules is as follows: In the previous work, the 'Perpendicular', i.e. the distance of the tip of the shadow from the east-west line, was calculated, given the Sun and the shadow, and from that the 'Base' and the direction were calculated. Here, given the distance and the 'Perpendicular', the Sun is computed. Therefore this is the converse of the previous work, and can be derived from that. Steps (i) and (ii) are the same as steps (i) and (ii) of the previous work, and have been derived there. We shall therefore derive (iii), (iv) and (v) from (iii), (iv) and (v) there.

In the previous work in (iv), 'Perpendicular' = (*Sūryāgrā* ∓ Agrā) × shadow hypotenuse ÷ 120.
∴ 'The sine = (*Sūryāgrā* ∓ *Agrā)* = Perpendicular × 120 ÷ Shadow hypotenuse, as in (iii) here.

Since, 'the sine' = (*Sūryāgrā* ∓ *Agrā*), when the Sun is in the northern and southern hemispheres, respectively, *Agrā* ≐ *Sūryāgrā* ∼ 'the sine'. It has been mentioned that *Sūryāgrā* is always north, 'the sine' is either south or north according to the line to the tip of the shadow from the east-west line, and *Agrā* is south if the Sun is in the northern hemisphere and vice versa. Therefore, when *Agrā* is north, (i.e. when the Sun in the southern hemisphere,) 'sine' is north, and greater than *Sūryāgrā*. Therefore, in using ('the sine' — *Sūryāgrā*), we get that the Sun is in the southern hemisphere. If *Agrā* is south, and therefore to be got negative by the addition of *Sūryāgrā,* (i.e. when the Sun is in the northern hemisphere), and 'the sine' is north, *Sūryāgrā* is greater than 'the sine'. Here we have to use (*Sūryāgrā* — 'the sine'), and we get that when the Sun is in the northern hemisphere. If *Agrā* is south again, (i.e. the Sun is in the northern hemisphere, again), and 'the sine' is also south, then we have the case, *Agrā* = *Sūryāgrā* + 'the sine', in which case also the Sun is in the northern hemisphere.

From the *Agrā,* the sine of Sun's longitude is got thus: In step (iii) of the previous work, *Agrā* = Maximum declination × sine longitude of the Sun ÷ sin colatitude.
∴ sin long. of the Sun = *Agrā* × sine colatitude ÷ max. dec.
= *Agrā* sin colat ÷ 48′ 48″, as we get here in step (v).

The explanation of getting the Sun's longitude from its sine has already been given in connection with getting the sines for degrees (IV.1-15).

Another point to be noted in this connection is this: In what the author gives, there is nothing to say about the *addition* of 'the sine' and *Sūryāgrā* when they are of different directions, and therefore

about the Sun being in the northern hemisphere. But when they are of the same direction, and one is to be deducted from the other, the author mentions only the case where *Sūryāgrā* is to be deducted from the Sun (thereby assuming 'the sine' to be greater) the case in which the Sun is taken to be in the southern hemisphere.

We have seen that when 'the sine' and *Sūryagrā* are of the same direction, the Sun is to be taken as in the northern hemisphere in the case (iv) in which *Sūryagrā* is greater, and 'the sine' is deducted from it. The author has omitted to mention this case. Has he forgotten it? We think not. He hopes that the reader himself will infer the changes to be made in this contingency, *viz*, that 'the sine' is to be deducted from *Sūryagrā*, and as the result is to be considered negative, and as the *Agrā* thus got is negative it is to be taken as south, and as south *Agrā* is for the Sun in the northern hemisphere, the Sun in the northern hemisphere will be inferred.

As for TS and NP, here too they interpret *Sūryāgrā* as *Agrā*. They are not aware of the error that would be caused by this in the situation of the Sun, the hemispheres being reversed. For the matter of that they do not refer to the Sun's situation at all, nor to the contingency of the reversal the subtractor and the subtrahend.

[इति पञ्चसिद्धान्तिकायाम् वराहमिहिरविरचितायां करणाध्यायश्चतुर्थः] [1]

Thus ends Chapter Four entitled 'Three Problems: Time, Place and Direction in the Pañcasiddhāntikā composed by Varāhamihira

1. Col. A.C.D. इति करणाध्यायश्चतुर्थः

Chapter Five

PAULIŚA-SIDDHĀNTA — MOON'S CUSPS

५. पञ्चमोऽध्यायः
पौलिशसिद्धान्तः — चन्द्रश्रृङ्गोन्नतिः

Introductory

In this chapter the Moon's visibility after or before heliacal setting, the appearance of its horns at the time of visibility with its geometrical representation, and the daily rising and setting of the Moon with its time of reaching the meridian are dealt with. We can surmise that this chapter is a part of the *Pauliśa Siddhānta* because the things required for the computations like the declination of the Sun and the Moon with the latitude of the Moon, are available to us only from the *Pauliśa*, the *Romaka* and the *Saura* having not been dealt with as yet, and because the methods are too rough to be attributed to the *Saura.*

[चन्द्रदर्शनकालः]

अपमान्तरसंयुक्तात् तदूनगुणिताच्छशाङ्करविविवरात् |
मूलेनापमविवरे छिन्ने विक्षेपसंगुणिते || १ ||

फलमिन्द्वर्कविशेषाच्छोध्यं त्वयनानुकूलविक्षिप्ते |
तद्व्यत्यासे देयं विपरीतं पूर्वसन्ध्यायाम् || २ ||

Time of Moon's visibility

1. Find the difference in longitude of the Sun and the Moon, as also the difference of their declinations, (the mean declination of the Moon being used for this purpose). Multiply the sum of these two differences by their difference and find the square root of the product. By this 'square root' divide the product of the Moon's latitude and the difference of declination already found.

2. The 'result' is to be subtracted from the difference in longitude, if visibility in the west is in question and the latitude and *ayana* (i.e. course northward or southward) of the Moon are of the same direction, or added to the difference in longitude if of opposite directions. If visibility in the east is in question, reverse the subtraction and addition.

1-3. Quoted by Utpala on *BS* 4.15.

1a. A.D. अयातान्तर
b. A. ॰त्तद्धनयुक्ताच्छशांकविवरान्
c. A.D. मूलेनायनविवरे

2a. A. फलसिंध्वर्क
b. A1. छोध्यचयनानु॰; A2. छोध्यं च यनानु॰
c. U. च्छोध्यमपमानुकूल

दिनकृत्सप्तमभवनात्तेनोदयनाडिकाद्वयं यदि वा |
वियति विमले (तदे)न्दोर्लोकस्यालोक (आ)याति || ३ ||

3. In the case of the visibility pertaining to the west, if a segment equal to the corrected difference in longitude takes at least two *nāḍis* to rise in the east as reckoned by using the ascensional difference (for the place) of the seventh *rāśi* from the Sun, then the Moon will be visible, provided the sky is clear. In the case of visibility in the east, use the ascensional difference of the Sun's *rāśi* itself.

The following are the steps in the operation:-

i. Find the difference in the longitude of the Sun and the Moon.

ii. Find the difference of the Sun's declination, and the Moon's mean declination.

iii. The square root = $\sqrt{(\text{diff. in long. + diff. in dec.}) \times (\text{diff. in long.} - \text{diff. in dec.})}$

iv. Result = diff. in dec. × Moon's lat ÷ the square root.

v. Corrected diff. in long = diff. in long ∓ result. (Of ∓ the upper sign is to be used if visibility pertains to the west, and the latitude and the course of the Moon are of the same direction, or if the visibility pertains to the east and the latitude and course of the Moon are of different directions. The lower sign is to be used otherwise.

vi. If the visibility pertains to the west, find the time of rising of an ecliptic segment equal to (v), by using the ascensional difference (for the place) of the seventh sign from the Sun and Moon. If it pertains to the east, use the ascensional difference of the Sun's *rāśi* itself. If the time so found is greater than two *nāḍis,* the Moon is visible; otherwise it is not visible.

The time that we find in (vi) is the time of Moonset after sunset in the west, and the time of moonrise before sunrise in the east. The sun, Moon, declinations and latitude of these times should be used and the work repeated for greater accuracy. Other *siddhāntas* mention this, though the author here has not done so specifically. Or, even before beginning the work, we can know the approximate times of moonset and moonrise, and do the work using the elements of these times.

Near the time of new moon the Moon is invisible because the lighted up part is very small, and the sky itself is bright by the nearness of the Sun below the horizon. It has been fixed by the ancient authors by observation, that if the Moon sets within two *nāḍis* after sunset, or if the sun rises within two *nāḍis* after moonrise, the moon is not visible. (In places near the equator this criterion will be satisfied if the elongation of the Moon is in the neighbourhood of twelve degrees.) It is this we are finding by the computation, and it is obvious that the nearer the time of the elements used to the result, the better will be the result itself. Therefore is the need for successive approximation.

If it is only for the sheer beauty of its appearance in the sky which has been described by poets like Kālidāsa, the first digit of the Moon is fit to be sought. But it is necessary for religious purposes

3b. A.॰नोदया. c.A.तदिन्दो
d. A.C.D.U.लोकमायाति ।

also. The Baudhāyanas have to avoid *Iṣṭi* being performed on the day of the first appearance of the Moon, and do it on the previous day, and the offerings to the manes have to be done on the day previous to the *Iṣṭi*. The Dharmaśāstras describe the seeing of the first digit of the Moon as meritorious. The Muslims consider their months ending with the first appearance of the Moon, and so this is important to them for calendrical purposes. The observance of the last digit of the Moon was necessary in ancient times, for from that they had to determine whether the same day or the next one would be the new moon day, so necessary for their religious rites. The importance can be guessed from the special names they had for the days at new moon, *Sinīvālī* and *Kuhū* in which the streak of the Moon will be visible and invisible, respectively.

Example 1. At a certain place having lat. 30°N. examine the visibility of the Moon in the evening, given, the Sun at sunset = rāśi 1-0, the Moon at sunset = rāśi 1-15, and the Moon's latitude = 240′ south.

From the Sun and the Moon, their respective declinations are 704′N and 1004′N (mean). From the latitude 30°N, and Sun's declination the *vināḍis* of ascension at the place, of Scorpio, the seventh *rāśi* from Sun and Moon, can be calculated to be 355. From these,

i. Diff. in long = rā. 1-15 − rā. 1-0 = rā. 0-15 = 15°.

ii. Diff. in dec. = $1004' - 704' = 300' = 5°$

iii. The square root = $\sqrt{(15° + 5°) \times (15° - 5°)} = 14° 8'.4$

iv. The Result = $5° \times 4° \div 14° 8'.4 = 85'$.

v. Corrected diff. in long = $15° + 85' = 16° 25'$, (the lower sign, because the work pertains to the west (evening) and the Moon's latitude is south, while its *ayana* is north),

vi. As the work pertains to the west, the seventh *rāśi* measure is to be used, which we have found to be 355 *vināḍis*. Using this, the time taken for 16° 25′ to rise is $16° 25' \times 355 \div 30° = 194$ *vināḍis*. This is more than 2 *nāḍis* and so the Moon will be visible. As the time found is far above the requirement, we need not repeat the work using the elements of the time of moonset.

Example 2. At a certain place (north of the equator) on a particular day in the evening the Sun rā 6-0. The Moon is rā. 6-15. The Moon's latitude is 4° 40′. The equinoctial shadow of the place is 4 digits. Examine for Moon's visibility.

From the Sun, its declination is 0′, and from the Moon its mean declination is 363′ S. From the equinoctial shadow and the Sun's declination, the measure of the ascension of Aries, (seventh from Sun and Moon, since the computation pertains to the west) can be calculated to be 228 *vināḍis*. Using these,

i. diff. in long. = *rā* 6-15 − *rā* 6-0 = 15° = 900′

ii. diff. in dec. = $363' - 0' = 363'$.

iii. The square root = $\sqrt{(900' + 363') \times (900' - 363')} = 823'.5$

iv. The result = $363' \times 280' \div 823.5 = 123'.4$

v. The corrected diff. in long. = $900' - 123'.4 = 12° 56'.6$ (The upper sign because, the work pertains to the west, and the *ayana* and latitude of the Moon are of the same direction.)

vi. As the work refers to the west, using the measure of Aries, the seventh *rāśi* from Sun and

Moon, the time for a segment equal to 12° 56′.6 to rise is, 228 × *12°* 56′.6 ÷ 30 = 99 *vināḍis*. This is less than 2 *nāḍis* and so the Moon will not be visible that day. As the time got is far less than the requirement, repetition of the work is unnecessary.

The steps are explained thus:

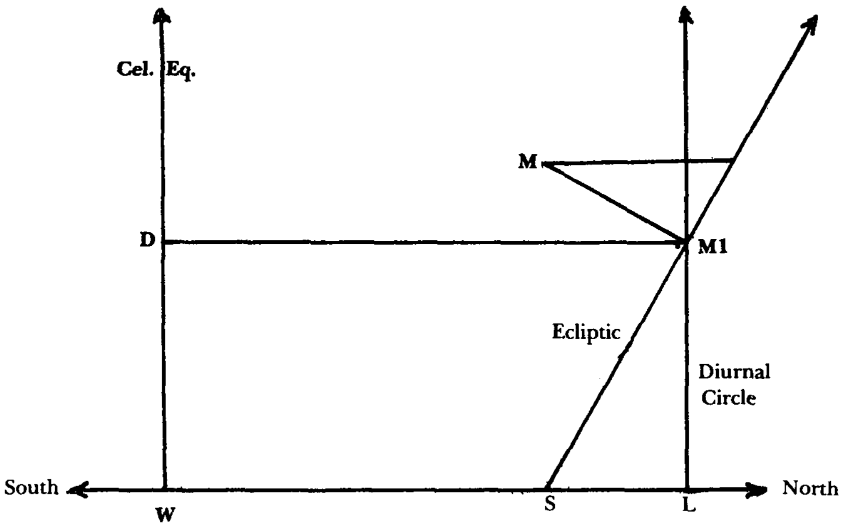


Fig. V. 1

Here, WD is the celestial equator. SM'C is the ecliptic and LM′ is the diurnal circle of the Moon projected on the ecliptic. S is the Sun, M is the Moon and M′ is the same projected on the ecliptic. MM′ is the Moon's latitude.

SM′ is the difference in longitude which is found in step (i). WS is the Sun's declination, and DM′ is the Moon's mean declination.

∴ SL is the difference of the declinations, found in step (ii). Assuming the triangles as plane triangles, in the right angled triangle SLM′,

$LM'^2 = SM'^2 - SL^2 = (SM' + SL)(SM' - SL)$

$\therefore LM' = \sqrt{(SM' + SL)(SM' - SL)}$, and

LM′ being the square root, it is equal to $\sqrt{(\text{diff. in long.} + \text{diff. in dec.})(\text{diff. in long} - \text{diff. in dec.})}$.... (step iii)

M′C is the result and it is found thus:

As MM′ is perpendicular to SC, triangle MM′C is right angled at M′.

∴ angle SM′L = angle CMM′

Therefore the two triangles are similar.

∴ M′C/MM′ = SL/LM .

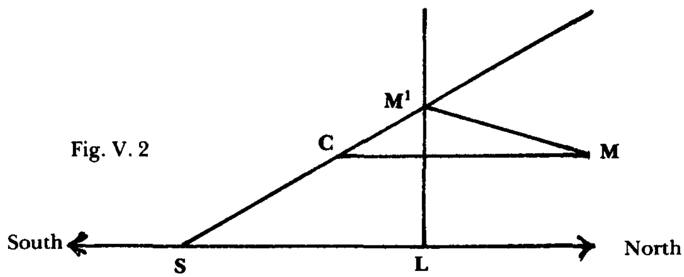
$\therefore$ M′C = SL× MM′ ÷ LM′, i.e. 'the result' = difference in declination × moon's latitude ÷ 'the square root', (which is step iv).

Now for the additive or subtractive nature of 'the result':

If the Moon's *ayana* is northward, i.e. if the ecliptic is inclined northwards (as in fig. 1), the Moon having south latitude, being at the end of a perpendicular to it, is lifted up. Therefore the Moon projected at M′ is projected at C, as it were, and the difference in longitude which is the distance between S and M′, is increased. So, in this case, 'the result' M′C is to be added.

Now consider the case, when the *ayana* does not change, but the latitude also is north, like the *ayana*, as in Fig. 2.

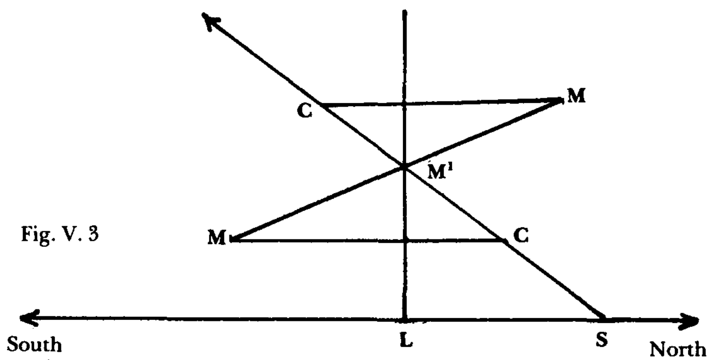
Fig. V. 2



Now, clearly the Moon M at the end of M'M is bent downwards, with the result that M'C is deductive in this case, as the instruction says.

Let us next consider the case when the Moon's *ayana* is southward as in Fig. 3.

Fig. V. 3



Clearly in this case the Moon having north latitude is lifted up, and 'the result', CM', is additive, and the Moon having south latitude is depressed, and CM' is subtractive. Thus we have, for *ayana* and latitude having identical direction, 'the result' is subtractive and having different directions it is additive. This is for visibility in the west.

Now, for the visibility in the east: we are now looking eastward and successive points on the ecliptic are lower and lower towards the horizon. Therefore in figs. 1, 2 and 3, other things being the same, the ecliptic alone is to be represented as being directed downwards, as in Fig. 4.

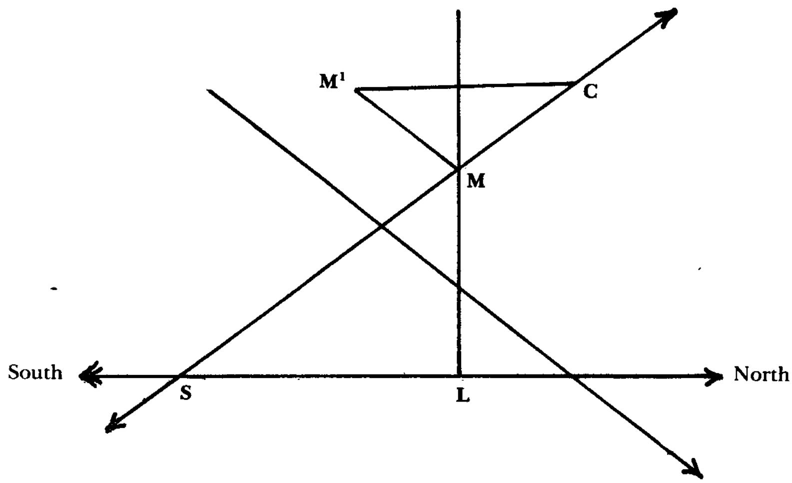


Fig. V. 4

Therefore, in each case taken up for consideration above, the direction of the *ayana* being changed, we see that for the *ayana* and latitude having different directions, 'the result' is subtractive, and having the same direction it is additive. Thus step (v) is explained.

Now for step (vi). We have already said that the Moon will be visible if it does not set within two *nāḍis* after sunset, or if it rises before 2 *nāḍis* before sunrise. (As visibility depends actually on other factors like the keenness of the eyesight of the observer, we have only to take the authority of the *Śāstras* in this matter). So in the evening we have to find the time by which the Moon will set after sunset, i.e. the segment constituting the corrected difference in longitude will set. As the distance between the rising and setting points in always in 6 *rāśis*, this time is equal to that of the rising of an equal segment in the east, which can be calculated by using the *vinaḍis* of the ascensional difference of the rising sign, which being six *rāśis* away, is the seventh from the Sun (or Moon). If this time is greater than 2 *nāḍis*, the Moon would not have set, and therefore be visible. In the matter of visibility in the east, the same explanation holds, except that now the time of rising of the segment in the east is wanted, using the ascensional difference of the rising sign in which the Sun (or Moon) itself is situated, and hence the instruction to use that sign.

This instruction to use the ascensional difference of the same sign as the Sun in the case of visibility in the east is implied by the use of the word *vā*, though not explicitly stated, and can also be inferred from the nature of the explanation. TS-NP do not seem to have noted the difference in the methods to be pursued in the operation. Another mistake they have made is that they have discarded the correct reading, *ayanānukūlavikṣipte* (*v*. 2) and chosen the incorrect reading *apamānukūlavikṣipte* and accordingly, have given the condition for additiveness or subtractiveness, "If the moon's latitude is

of the same direction as the difference in declination etc." Declination had direction, but what direction can be attributed to the difference in declination as given in the text? Or how can the word for declination mean difference in declination? Whatever the latitude, 'the result' is zero at the junction of the *ayanas*, which means its sign, i.e. its additiveness or subtractiveness changes there, and therefore the *ayana* should be a criterion for additiveness or subtractiveness. The very name of this correction, *Āyanadṛkkarma* (this name is not mentioned here by the author, but it is this) will suggest that the *ayana* of the Moon must form part of the criterion.

Another thing must be mentioned: The work given here is very rough, because spherical triangles are taken as plane triangles, and another correction called *Ākṣadṛkkarma* which is to be done for the sake of the latitude of the observer has been omitted. Therefore the reader should refer to works like the *Mahabhāskarīya* and *Siddhānta Śiromaṇi* for greater accuracy.

[चन्द्रश्रृङ्गोन्नतिः तत्परिलेखश्च]

द्विगुणेऽ(क्षे) 'तिथ्यंशः' शृङ्गमुदक् तुङ्गमुडुगणाऽधिपतेः |
देयं च भुजादेतच्छौक्ल्यं कर्णाद् द्विषट्कांशम् || ४ ||
अपमान्तरविक्षेपा(वे)कान्यत्वे युतोनितौ कोटिः |
कर्णो रवीन्दुविवरं तत्कृतिविवरात् पदं बाहुः || ५ ||

Diagram of the Moon's cusps

4. Multiply the latitude of the place in degrees by two and divide by fifteen. By the resulting number of *aṅgulas* or digits (measured along the rim), the northern tip of the horn of the Moon should be raised upwards (as caused by the latitude at the time of first visibility). This raising should be directed upwards like the '*Bhuja*' which we are going to mention. The number of digits of illumination of the Moon's orb, (usually called merely digits), is the twelfth part of the difference in longitude in degrees, last found, and should be directed like 'Hypotenuse', which we are going to mention.

5. The difference in declination last found should be added to the Moon's latitude or subtracted from it, as the directions of the Moon's *ayana* and its latitude be the same or different. (This refers to the visibility in the west in the evening. With reference to the visibility in the east in the morning, the addition and subtraction, is done vice versa). The result is called '*Koṭi*'. The difference in longitude is called 'the Hypotenuse'. The '*Bhuja*' is the square root of the difference of the squares of the 'Hypotenuse' and the '*Koṭi*'.

4-7. Quoted by Utpala on *BS* 4.15.
4a. A. दिगुणेच्छे; C.U. दिनगुणेच्छा; D. द्विगुणाक्षे
b. A. शृंगमुदक्कुंमुडुगुणाधिपतिः
d. A. कर्णाद्विषट्कांशः D. कर्णद्विषट्कांशः

5a. A. अनांतर; C.D. अयनान्तर. A1. विक्षेपा; A2. धिक्षेपा
b. A1.2. वैकानत्वे; A2. वैकानचे U. वैकान्यत्वे A. यातोनिता; C. युतोनिता
c. A. रवीदुविवरं

सविता यतः शशाङ्कात् कोट्या परिकल्पितस्ततः कोटिः |
देयांऽशकाङ्गुलसमा भुजकर्णौ चाङ्गुलैरेव || ६ ||
शशिमध्यात् प्राक् कर्णः कोटिरतोऽतो भुजः शशाङ्कगतः |
परिधावक्षो(न्ना)मः शौक्ल्यं मध्याद्धनुस्तत्र || ७ ||

6. The *'Koṭi'* is to be drawn on that side of the Moon towards the Sun, north or south, which is got in computing it, using the scale, one *aṅgula* = one degree of *'Koṭi'*. The *Bhuja* and the Hypotenuse also should be drawn to the same scale.

7. Thus, first there is the Hypotenuse from the centre of the Moon to that of the Sun. From the centre of the Sun the *'Koṭi'* is laid in the direction computed for it. Then from its termination the *'Bhuja'* is laid towards the Moon's centre. On the rim of the Moon represented by a circle of fifteen *aṅgulas*, the raising of the horn in *aṅgulas* due to the latitude of the place is to be done. At the centre of the two ends of the horn the illumination in digits is to be represented on the diameter. There the arc (forming the upper boundary of the illumination) is to be drawn (by making the arc pass through the two ends of the horn and the point in the middle to which the illumination extends).

Though it is plain that these four verses give instructions for the graphical representation of the Moon at the times of visibility, (specifically its first visibility in the evening in the west), yet on account of possible incorrect copyings, and because we are not sure of the degree of roughness of the result intended by the *Siddhānta*, we encounter a lot of difficulty in ordering the words and interpretting them. The author has not given the diameter of the Moon in *aṅgulas*, which is necessary to draw the orb, and represent in it the illumination and the uplifting of the horn. But we can infer the diameter to be fifteen *aṅgulas* thus: On *Aṣṭamī*, at the middle of either fortnight, when the hypotenuse is 90°, according to the rule for getting the illumination, we have 90/12 = 7½ *aṅgulas* of illumination. We know that half the Moon is illuminated then, and therefore the whole Moon should have a diameter of fifteen *aṅgulas*, as we have stated.

This agrees also with the 'elevation of the horn' due to the latitude, which can be shown thus: The line joining the tips of the horn seen horizontal by a person on the equator, is seen vertical by a person at the pole, i.e. at 90° latitude, because the celestial equator is inclined by 90° there, so as to be coincident with the horizon. As the hypotenuse at the time for which the elevation is required is small, we can take it that the elevation of the *horā* is proportionate to the degrees of latitude. According to the rule for elevation given by the author, it is for 90° and 90 × 2 ÷ 15 = 12 *aṅgulas*, along the rim of the quadrant, from the horizontal to the vertical. Therefore the whole rim, i.e. the circumference, is 4 × 12 = *aṅgulas* and this shows that the diameter must be 48 × 7/22 = fifteen *aṅgulas* very nearly. This agreement in the diameter, as calculated by the two rules, itself is a criterion for the correctness of the rules.

6b. A.कोज्यापरिकल्पितकोटिः

7c. A.॰वक्षोनामः; C.D.U.॰वक्षो नाम
d. D.शौक्ल्यमध्यात॰
A.तदनु सूत्रं; D.तदनु [च] सूत्रम्'

Now, we shall show why this elevation is always on the northern limb. As mentioned several times before, when latitude is used in the rules given, it is always north latitude that the author means. As seen from north latitudes, the circles on the stellar sphere are all bent towards the south above the horizon. Therefore the hypotenuse also is inclined south, the angle of inclination being equal to the latitude, the hypotenuse being small and taken as a straight line. By this inclination south, the line joining the tips of the horns, which is perpendicular to the Hypotenuse is elevated in the north and depressed in the south, the angle of elevation being equal to the latitude. This elevation, measured on the rim in *aṅgulas* is, as we have shown, twice the latitude divided by fifteen.

In the matter of the addition or subtraction of the difference of declination and the Moon's latitude, we have said that the author has in view only the visibility in the west in the evening, for then alone is the statement correct. Perhaps the author thinks that this is enough, because the elevation of the horn at evening appearance alone is observed anxiously by people, as an omen of good or evil. Or the author thinks that the readers themselves will understand the reversal of addition and subtraction for the morning appearance, by analogy with what was done before in the case of visibility. It must also be noted that the object here is only to represent the orb of the Moon as it appears, and the Hypotenuse, *Bhuja* and *Koṭi* are given to serve this end. Therefore it would not matter if these are represented on a different scale from that on which the Moon is given, as for instance an *aṅgula* per degree here. (On this scale the Moon will have to be represented by a diameter of a half-*aṅgula*.)

There is a view that the elevation of the horns should be observed when the orb of the Moon is on the horizon. In that case, the Sun will be below the horizon, and the question of the difference in scale will not arise at all.

So, these are the steps in the work:-

i. The elevation of the horn due to latitude in *aṅgulas* = latitude in degrees × 2 ÷ 15.

ii. Illumination or digit of illumination in *aṅgulas* = the difference in longitude in degrees ÷ 12.

iii. *Koṭi* in *aṅgulas* = diff. in declination in degrees ± latitude in degrees. (For evening in the west, if the Moon's latitude and *ayana* are of like direction, addition, and if of different directions, subtraction. For morning in the east, reverse the addition and subtraction).

iv. Hypotenuse = *aṅgulas* equal in number to difference in longitude.

v. *Bhuja* in *aṅgulas* = $\sqrt{\text{Hypotenuse}^2 - \text{Koṭi}^2}$.

vi. See fig. 5, below. On the surface on which the phenomenon is to be represented draw a horizontal line and mark the north and south sides on both ends. Mark the point S on it to represent the Sun. Mark a point A on the horizontal line on the side in which the Moon is situated, (this is known when finding the *Koṭi*) such that SA = *Koṭi*. From A draw a perpendicular upwards equal to the *Bhuja* and at the end mark M, the centre of the Moon. MS is the Hypotenuse. With M as centre draw the orb of the Moon having a diameter of 15 *aṅgulas*. At M draw a diameter BC perpendicular to the Hypotenuse. From the northern end the diameter, say C, measure the *aṅgulas* of elevation due to the latitude of the place, along the rim, and mark the point D. Draw the diameter DME. D and E are the tips of the horns. On the lower semicircle caused by DE, mark its mid-point, F. Draw the radius FM. On this mark a point G, such that FG = the *aṅgulas* of illumination. Draw the arc DGE by the well-known method of making a circle pass through 3 points. This is the upper limit of the illumination. The figure of the Moon is now as it will be seen in the sky. The horizon is between the Sun and the Moon, parallel to the original horizontal line. It must be remembered that

what the *Siddhānta* gives is only approximate, though easy to do, and for greater accuracy, we have to do a lot of work like calculating the Great gnomons of the Moon and the Sun etc.

Example 3. Represent graphically the Moon of example 1. There, we are given, latitude of the place = 30°N, the Moon's ayana is northward, and its latitude 4°S, and we get the difference in longitude = 15°, and the difference in declination = 5°.

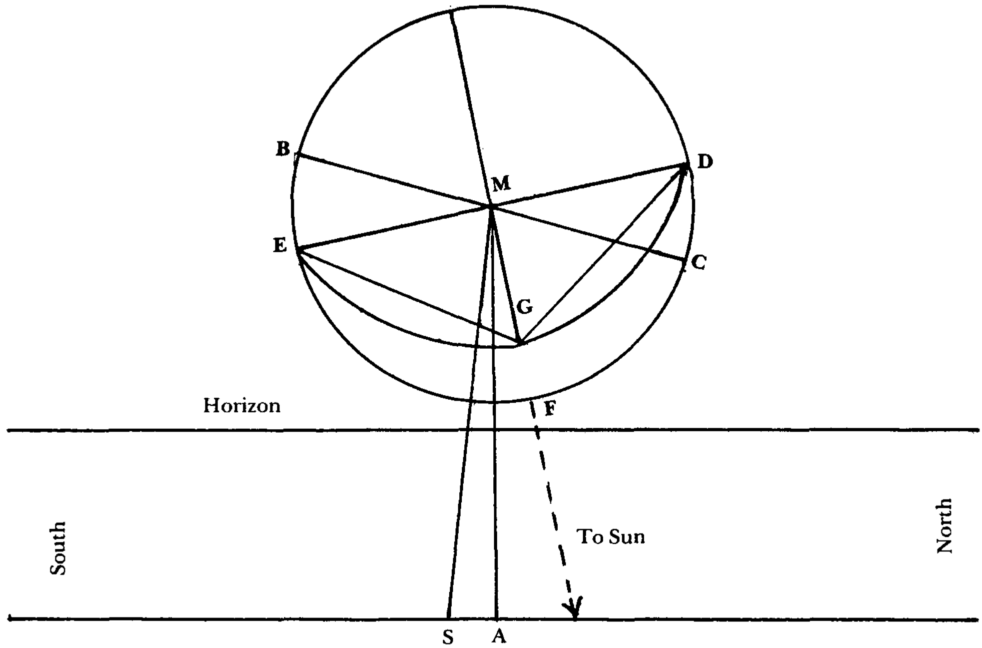


Fig. V. 5

From the data given above:

i. The *aṅgulas* of elevation due to the latitude of the plane = 30 × 2 ÷ 15 = 4.

ii. *Aṅgulas* of illumination = 15 ÷ 12 = 1¼.

iii. *Koṭi* = 5° − 4° = 1°, and ∴ 1 *aṅg.*, the Sun being to the south, (because it is evening observation, and Moon's *ayana* and lat. are of diff. direction).

iv. Hypotenuse = 15 *aṅgulas*.

v. *Bhuja* = $\sqrt{225-1}$ = nearly 15 *aṅgulas*.

vi. Representation: Fig. 5: (Scale 1' unit = 6 *aṅg.*)

It should be remembered that the fig. is intended only for the appearance of the Moon, with the illumination, and elevation of the horns represented on it, and none else. The line DGEFD is the part illuminated, D and E being the tips of the horns. Actually the Sun is down, on the line MF.

Now for the readings: As the elevation due to the latitude of the place is considerable, it cannot be neglected and must be represented; therefore we have corrected *dviguṇeche tithyamśa* into *dviguṇe'kṣe tithyaṁśa*, by changing *cha* into *kṣa*. But TS have adopted the reading *dviguṇecchātithyaṁśa* and considering it a combination of *dviguṇecchā* and *atithyaṁśa* thinking that the subject matter is astrological, (which is obviously unlikely).

We have corrected *paridhāvakṣonāmaḥ* into *paridhāvakṣonnāmaḥ*, for the instruction to apply the elevation due to the latitude must be given. But TS and NP take the reading as it is, and say that something on the rim of the Moon is named *akṣa*, which is purposeless. Their readings themselves in these two cases are from their own edition of *Bhaṭṭotplala's* commentary on the *Bṛhatsaṁhitā*, and to say that their (TS's) readings agree with those of the *Bhaṭṭotpala* may be improper, for probably they have themselves put the readings there.

[चन्द्रस्य दैनन्दिनोदयास्तौ]

याम्योदग्विक्षेपाद्विषुव(द्धा)घ्ना'द्रवि'भिरवाप्तांशाः |
उदये शशिनो वृद्धिः क्षयो विपर्यस्तमस्तमये || ८ ||

एवं व्यर्क्काच्चन्द्राद्यद्यूना राशयः षडधिका वा |
तदुदयकालेन दिवा निशि च शशाङ्कोदयो वाच्यः || ९ ||

Daily rising and setting of the Moon

8. Multiply the Moon's latitude in degrees by the equinoctial shadow and divide by twelve. Add the resulting degrees to the longitude of the Moon, or subtract from it, according as the Moon's latitude is south or north, if the times of daily moonrise is to be computed. If the times of daily moonset is to be found, reverse the addition and subtraction, *i.e.* subtract and add, respectively.

9. Subtract the longitude of the Sun from that of the Moon corrected thus. Find the time for this segment of the ecliptic to rise, after sunrise. By so much time after sunrise, the Moon will rise. If this segment is less than six *rāśis*, then the moonrise will fall in the day-time, if greater, the moon will rise at night.

8-10. Quoted by Utpala on *BS* 4.15.

8b. A.॰द्विषुवज्याघ्नाद्द; C.द्विषुवत्याघ्नाद्;
D.॰दिषुवच्छा [या] घ्नाद्
A.रविस्तरांशाः; D.रविभक्तांशाः; U.रविभिरवाप्तांशः

d. U.विपर्यस्तमय एवम् ।

9a-b. A.व्यर्क्काच्चाद्येनोना

b. C.षट्कोनाः; D.द्येनोना. A.षडधिका या

c. A.तदुदया
B1.2.3. Commence again from ॰न दिवा after the big gap which commenced at IV.20.

d. A.निशे. B3.शशाकोदयो

कृत्वैवं क्षयवृद्धी व्य(र्काच्चन्द्राद् वि)शोध्य चक्रा(र्धम्) |
शेषोदयकालसमे शशिदिवसा(न्ते) शशी मध्ये || १० ||

10. In the manner given (in verse 8), correct the Moon for moonset, deduct the Sun from this corrected Moon, and deduct 6 *rāśis* from the remainder. Find the time by which the remaining segment will rise, after sunrise. This is the time from sunrise when the Moon will set. At the time exactly midway between moonrise and moonset, the Moon will reach the meridian, (*i.e.* will be at upper culmination).

The following is the work to be done:

i. The correction (for latitude) = the Moon's latitude × the equinoctial shadow ÷ 12 (This is known as *Akṣadṛkkarma*).

ii. This correction is to be applied to the true Moon. Corrected Moon = True Moon ± Correction. (If the time of moonrise is to be found, then the correction is subtractive if the Moon's latitude is north, and additive if it is south. If moonset is wanted, if the Moon's latitude is south, the correction is subtractive, if north it is additive).

iii. The time of moonrise is found thus: The corrected Moon − True Sun = elongation. The time of rise of the segment of elongation from sunrise is the time of moonrise. (In other words, the corrected Moon's position on the ecliptic being known, the time when that point rises is the time of moonrise). When the elongation is less than 6 *rāśis*, moonrise is in the day-time, otherwise at night.

iv. The time of moonset is found thus: Corrected Moon − Sun = elongation. The time of rise of (the segment of elongation − 6 *rāśis*) from sunrise, is the time of moonset. (In other words, the time of rising of the point diametrically opposite to corrected Moon is the time of moonset). Here, if the elongation is less than 6 *rāśis*, then the moonset is in the night, and if greater, it is in the day-time.

v. Moonrise to moonset is the moon-day-time. It is obvious that at the middle of its day time it is on the meridian.

It is obvious that the times of rising and setting will be correct if the longitudes and Moon's latitude of those times are used. But as the computation as done here is only approximate, we can guess the approximate times of moonrise and moonset for the day from the *tithi* of the day, and use the elements of those times, to get tolerably accurate times.

Example 4. The equinoctial shadow for a certain place (in the northern hemisphere) is 4 aṅgulas. The ascensional differences for the place are for Aries 236 vināḍis, Taurus 265, Gemini 309, Cancer 337, Leo 333,

10a. A. क्रत्वैवं; B. तच्चैवं. A.B. वृद्धि
b. A.B.C.D. U. व्यर्कं; (B2. व्यर्क) चन्द्रं विशोध्य चक्रार्धात्
c. A. शेखोदय; B. मेषोदय
d. B3. षशि and C.D. निशि for शशि
A.B.U. दिवसार्द्धे;. D. दिवसेऽस्तं
A.B. शशिमध्येः; C. शशी याति

Virgo 320, Libra 320, Scorpio 330, Sagittarius 337, Capricorn 309, Aquarius 265, and Pisces 236. There, on a certain day, the true longitude of the Moon at sunrise is rā, 1-18, the true Sun is rā. 10-3, the Sun's daily motion is 60′, the Moon's daily motion is 840′, the latitude of the Moon is 272′ S, and its motion per day 8′ S. Find the moonrise, moonset and upper culmination.

The distance of the Moon from the Sun = *rā*. 1-18 – *rā*. 10-3 = *rā*. 3-15, (equal to 8¾ *tithis*). From this the approximate time of moonrise is, 8¾ × 2 = 17½ *nāḍis*. Therefore the time of moonset is approximately, 17½ + 31 = 48½ *nāḍis*. The Sun at approx. moonrise is *rā*. 10-3-18, the moon *rā*. 1-22-5, and its latitude 274′ S. At approximate moonset, the sun is *rā*. 10-3-49, the Moon *rā*. 1-29-19, and its latitude 278′ S.

Using each set, the computation is as follows:

i. The correction for moonrise = 274′ × 4 ÷ 12 = 91′.

The correction for moonset = 278′ × 4 ÷ 12 = 93′.

ii. The corrected Moon for moonrise = rā. 1-22-5 + 91′ = *rā*. 1-23-36.

The corrected moon for moonset = *rā*. 1-29-19 – 93′ = *rā*. 1-27-46.

iii. Computing Moonrise:

Elongation = Corrected Moon – Sun = *rā*. 1-23-36 – *rā*. 10-3-18 = *rā*. 3-20-18.

As this is less than six *rāśis*, the moonrise is in the day-time.

The time for the segment, *rā*. 3-20-18, to rise after sunrise is found thus: For the rest of Aquarius, which is the sign occupied by the Sun, to rise, the time taken is 265 × 1602′ ÷ 1800′ = 236 *vināḍis*. For Pisces to rise, 236, for Aries 236, for the corrected Moon to rise in Taurus, 265 × 1416′ ÷ 1800′ = 208 *vināḍis*. So the total time taken is, 236 + 236 + 236 + 208 = *nāḍis* 15-16. This is the time of moonrise.

iv. Moonset:
Elongation = Corrected Moon – Sun
= *rā*. 1-27-46 – *rā*. 10-3-49 = *rā*. 3-23-57.

Deducting six *rāśis* from this, we have *rā*. 9-23-57.

The time for the rise of this much segment is found thus: For the rest of Aquarius to rise, the time taken is 265 × 1571′ ÷ 1800′ = 231 *vināḍis*. For Pisces 236, Aries 236, Taurus 265, Gemini 309, Cancer 337, Leo 333, Virgo 320 and Libra 320. For Scorpio to rise upto the point diametrically opposite to the corrected Moon, 333 × 1666′ ÷ 1800′ = 308. Adding up, the time of moonset is *nā*. 48-15.

This agrees with what we can infer from elongation, for the elongation found is less than 6 *rāśis*, and the moonset must be in the night.

v. The duration of the lunar day is *nā*. 48-15 – *nā*. 15-16 = *nā*. 32-59. Half this is *nā*. 16-30. Adding this to moonrise, mid-moon-day, the time of upper culmination of the Moon is *nā*. 15-16 + *nā*. 16-30 = *nā* 31-46, after sunrise.

The instruction is thus explained: The problem is to find the time of rising or setting of the Moon, which is in its orbit, at a distance equal to its latitude from the ecliptic. If it can be projected

on the ecliptic in such a way that its projected position rises and sets at the same time as it itself rises and sets, then the time can be found like *lagma*, by the method given in Chap. IV for that purpose.

In order to effect the said projection two corrections have to be applied to the Moon, one for the inclination of the ecliptic called *Ayana-dṛkkarma* (we did this for visibility), and the other for the latitude of the observer called *Akṣa-dṛkkarma.* The *Siddhānta* gives the correction for latitude alone here, which is got by multiplying the latitude of the Moon by the equinoctial shadow and dividing by 12.

The following is its rationals: The latitude is measured on the great circle perpendicular to the ecliptic and directed towards the pole of the ecliptic. If the latitude is projected on secondaries to the pole, and we get the true declination of the Moon by adding this to the mean declination, we can find its time of rising and setting directly, as we find the rising and setting of the Sun, by computing its *cara* etc. and getting its own ascensional differences. But if the latitude is small, it can roughly be taken as the correction for the Moon's mean declination, given by its longitudes. So the correction to the *vināḍis* of true *cara* can be found by the latitude taken as part of the declination, by proportion from the *cara-vināḍis* for the mean declination already used in finding the ascensional differences. Therefore, as in getting the *cara-vināḍis*, here too we have to multiply by the equinoctial shadow and divide by 12. But the division by the diurnal radius is not done, because here we are not finding actually the *vināḍis* of *cara*, but an element of the ecliptic corresponding to the *cara*, for the sake of which we have to multiply again by the radius of the diurnal circle, and the two cancel out. Thus the correction will permit us to consider the Moon to be on the ecliptic.

We shall now consider when it is additive, and when subtractive. In the northern hemisphere, the *Unmaṇḍala* is elevated above the horizon, the elevation increasing towards the north. Therefore if the Moon is a little to the south of the ecliptic on account of its south latitude, it rises later. As successive points on the ecliptic rise later and later, the correction got from the Moon's south latitude is equivalent to an increase in the Moon's longitude, and so the correction to the longitude is additive. From this we can see why the correction is subtractive if the Moon's latitude is north. As for the time of the setting of the Moon, the further north a body is, the later it sets, and therefore the correction is additive if the latitude is north, from which we see it is subtractive if the latitude is south. The *Siddhānta* has in view only observers in the northern hemisphere, as we have already said. We have already drawn the attention of the reader to the omission of the correction due to the inclination of the ecliptic (*Āyana-dṛkkarma*). It may be that the author expects us to make this correction also, taking the hint from the computation of the heliacal rising of the Moon (visibility).

The part of the instruction to find the time when the corrected Moon rises is explained thus: The corrected Moon *minus* Sun is the segment of the ecliptic between them, and the time taken for its rise after sunrise is the time of the rise of the corrected Moon itself. If this segment is less than six *rāśis*, the Moon must rise in the day-time, because just after the rise of six *rāśis* from sunrise the sun sets, but this segment is less. Clearly, if it is more than six *rāśis* the Sun has set, and it is night when the Moon rises. As for moonset, the point of the corrected Moon *plus* (or *minus*) six *rāśis* rises at that time. So, the time of its rise, or which is the same, the time taken by the corrected Moon *minus* Sun ± six *rāśis*, after sunrise is the time. Of ±, the author has chosen minus, because the effect of both is the same. By analogy with mid-day Sun, the Moon is on the meridian at the middle of its day-time, provided its motion and change of declination is tolerably uniform. We must add here that it would have been sufficient if the author had said, 'Treat the corrected moon as *Lagna*, and its time of rise is the time of moonrise. Treat the corrected Moon *plus* (or *minus*) six *rāśis* as *Lagna*, and its time of rise is the time of moonset'.

Now for the readings: In verse ten if the meaning is taken as it is, then we shall be getting the time of sunset after moonrise, which serves no purpose and cannot be the intention of the author to get, and it is incompatible with the time of the meridian Moon sought to be found in the fourth foot. This is the middle of the Moon's day-time and for this, moonset has to be found. (TS and NP too interpret this verse as giving moonset). Therefore we have corrected *vyarkam candram viśodhya cakrārdhāt* into *vyarkāt candrāt viśodhya cakrārdham,* by interchanging the case endings, and thus got the time of moonset, required for meridian Moon. The reading *meṣodayakāla* for *śeṣodayakāla* has been discarded as being unconnected with the problem.

TS and NP have given the impossible correction, *niśi divase'stam śaśi yāti* for *śaśidivasārdhe śaśīmadhya* found in the manuscripts. Their aim, viz. to get the time of moonset, is all right, but their interpretation of the stanza to get this is wrong, and also self-contradictory. See the Sanskrit commentary for the said interpretation: 'Deduct the Moon *minus* Sun from 6 *rāśis*; the time of the rising of this is the time of moonset, reckoned from sunrise. Here, if the Moon sets in the day-time then Moon-minus-Sun must be deducted from 6 *rāśis*. If in the night, the Moon itself is to be deducted from 6 *rāśis*. This order of procedure should be understood.' If their instruction in the first sentence is followed, the time of sunset after moonrise will be got, as we have already said, but not the time of moonset. It is to avoid this that we interchanged the case endings. As for the instruction in the second sentence, the first part of it disagrees with the second part. We shall illustrate these defects found in their interpretation, by applying them to two examples.

(a) The Sun is *rā*. 0-15, Moon is *rā*. 2-0, the Moon's latitude is zero, i.e. there is no corrections. In this case, the moonset according to TS is to be found thus: Moon − Sun = *rā*. 2-0 − *rā*. 0-15 = *rā*. 1-15. Deducting this from 6 *rāśis*, the remainder is *rā*. 4-15. They say, the time taken for *rā*. 4-15 to rise, after sunrise, is the time of moonset after sunrise. The absurdity of this can be seen by finding the time of moonrise, which is the time taken by the Moon-Sun to rise, *i.e.* for *rā*. 1-15 to rise; *i.e.* the interval between moonrise and moonset is the rising time of 3 *rāśis*. Or, by the instruction in the second sentence, as the Moon does not set in the day, it sets in the night, and therefore deducting the Moon itself from 6 *rāśis*, we get *rā*. 4-0, and they say by the time of rise of *rā*. 4-0 from sunrise the Moon sets. Does it occur in the night at all?

Perhaps they meant sunset. Then, let us take another case.

(b) The Sun is *rā*. 0-15, the Moon is *rā*. 8-0, and Moon's latitude is 0, again. Then, Moon − Sun = *rā*. 7-15. The moonset is in the day-time, clearly. Therefore deducting this from 6 *rāśis*, we have *rā*. 6-0 − *rā*. 7-15 = *rā*. 10-15. According to them the Moon sets by the rise of this segment after sunrise. Clearly according to this the moonset will fall in the night, and not in the day-time as required. Assuming sunrise is a mistake for sunset, reckoned from sunset also it will be wrong, for then the moonset will be *rā*. 4-15 from sunrise, which is wrong, for it is correctly the time of rising of *rā*. 1-15 from sunrise. This demonstration shows their interpretation to be wrong, and at the same time justifies our interchanging the case-endings, by which alone the time of moonset can be got correctly.

**[इति पञ्चसिद्धान्तिकायाम् वराहमिहरविरचितायां
शशिदर्शनम् नाम पञ्चमोऽध्यायः]** [1]

Thus ends Chapter Five entitled Pauliśa-Siddhānta: Moon's Cusps in the Pañcasiddhāntikā composed by Varāhamihira

1. Col.: A. शशिदर्शनं | B.C.D. इति शशिदर्शनम् ।

Chapter Six

(VĀSIṢṬHA-) PAULIŚA-SIDDHĀNTA: LUNAR ECLIPSE

६. षष्ठोऽध्यायः
वासिष्ठ-पौलिश-सिद्धान्तौ — चन्द्रग्रहणम्

Introductory

This chapter deals with the lunar eclipse. Nothing is given in the colophon at the end of the chapter about the *Siddhānta* to which this belongs. This cannot belong to the *Saura* for the lunar eclipse of the *Saura* is dealt with in Chapter X. The Sun, Moon and Rāhu of the *Romaka* are given in Chapter VIII, and in the same chapter the solar eclipse according to that *Siddhānta* occurs, and its lunar eclipse cannot be given here, earlier. Also, the method here does not have the refinement of the *Romaka* solar eclipse. So this chapter cannot belong to the *Romaka*. That it may belong to the *Paitāmaka* is out of question, since only the mean Sun and the Moon, and that very crudely, being given by the *Paitāmaha*, and Rāhu is not given. Also, the *Siddhānta* occupies a later chapter, the twelfth. This leaves the *Vāsiṣtha* and the *Pauliśa* for consideration. Perhaps it belongs to both combined, as we have observed in the case of their Moon and its daily motion. It cannot belong to the *Vāsiṣtha* separately for the *Vasiṣtha* does not give Rāhu, which we have to get from the *Pauliśa*. Also, it cannot belong to *Pauliśa* separately, for then at least part of the computation, like the duration of the eclipse will become redundant, because the duration of the lunar eclipse with its limits occurs in chapter VII also, together with the computation of the solar eclipse, which from the colophon and from the nature of the method given, must belong to the *Pauliśa*. Also, details usually given in connection with eclipses, like the direction of contacts, colour etc. are found only here in the VI chapter. Therefore we can conclude that chapters VI and VII belong both to the *Vāsiṣtha* and the *Pāuliśa*, and that the solar eclipse in the VII chapter belongs to the *Pauliśa*.

[समकलौ चन्द्रसूर्यौ]

नै(श्या) स्तिथिनाड्योऽर्के देया(श्चान्द्रे) समेन्दुरवि(वि)वरात् |
(दिवसोद्भवाश्च) शोध्याः स भवति तत्कालशशिलिप्तः || १ ||

Sun and Moon of equal longitude

1. Minutes of arc equal to the *nāḍis* of the full moon-*tithi* to go, after sunset, are to be added to the Sun, (which has been computed for sunset). Minutes of arc equal to the *nāḍis* to go from the end of the full moon or new moon-*tithi* in the day-time upto sunset are to be so added to the Sun. Thus corrected, the Sun becomes equal to the Moon in (degrees and) minutes at the end of the full or new moon-*tithi*, (i.e. at full or new moon).

The idea is that by thus finding the Sun, we can, without any trouble, get the Moon, for, if new moon, the Sun thus got is the Moon and, if full moon, the Sun *plus* 6 *rāśis* is the Moon.

The following is the rationale of the work: The lunar eclipse occurs at the end of full moon-*tithi*. At that time, the Sun and the Moon are separated from each other exactly by 6 *rāśis*. Therefore the degrees and minutes or, which is the same, the total minutes left over after finding the *rāśis* at 1800 minutes a *rāśi*, are the same for both. Therefore they are called *sama-liptas*, i.e. 'having equal minutes'. The solar eclipse is at the end of the new moon-*tithi*, at which time they are the same even in *rāśi*, not to speak of the degrees and minutes, and therefore *samaliptas*. So, if we know the Sun at these times, we know the Moon, for, if new moon, they are the same, and if full moon, different by 6 *rāśis*.

Now, in the *Pauliśa* the 'days from epoch' are found for sunset, and from them the Sun and the Moon are found for sunset first. (We have already drawn the attention of the reader to this, while commenting on III.15.) Then, the ending moment of the *tithi* is calculated by using the difference of their motions. The Sun's motion is roughly one minute of arc per *nāḍi*. Therefore if one minute per *nāḍi* of the time from sunset to full moon (we take only the full moon because with new moon at night there will be no solar eclipse) is added to the sunset Sun, the Sun at full moon is got, and the Moon is got from it by adding 6 *rāśis*. Thus the Moon is easily got, for otherwise we must calculate the Moon's motion during the interval by proportion from its daily motion, add this to the sunset Moon, and get the Moon. In the case when new or full moon-*tithi* ends in the day-time, it is obvious that the minutes of arc accrued during the interval up to sunset should be deducted from the sunset Sun, to get the Moon, as a preliminary to computing either the solar eclipse or the lunar eclipse.

The *Siddhānta* is content with thus getting the Moon roughly, for that will be sufficient considering the crudeness of its method of computation. If greater accuracy is desired, we must multiply the difference of the Sun's daily motion from 60 minutes of arc by the time to go or time gone, and, taking the product as seconds of arc, subtract or add them, respectively, to the Moon if the daily motion is less, and add or subtract respectively if greater. The daily motion required for this is given in III.17, which we have already seen.

TS have understood that the Moon at new or full moon is found here, but not the manner in which it is done so simply, for they interpret the instruction to mean that the Moon is to be got from its daily motion by proportion. To obtain this meaning, they make wild emendations of the words. But we have kept the words mostly as they are, and we can see that they are sufficient to give the correct idea. For example, in all the three readings, *naiṣyāḥ*, *naiṣṇāḥ* and *vaiṣṇāḥ (ṣnaiṣṇāḥ)* there is *'nai'* which therefore must have been in the original word. Therefore, by changing *ṣ* to *ś*, we get *naiśyāḥ*, meaning 'belonging to the night', which so well agrees with the idea. We have changed *candram* into *cāndra* for the sake of syntax and agreement with the idea. Between *vi* and *va*, we have introduced *vi*, thus reading *ravi-vivarāt*, which is a likely haplographical omission, and get a word that fits so well with the idea. Taking the meaningless reading, *nṛvaśudbhavācca*, and keeping as far as possible to the letters there, we have reconstructed the form as *divasodbhavācca*, fitting in with the

1a. A.B2.D. नैष्याः; B1.3. नैष्णाः; B3. वैष्णाः;
C. यातैष्या A.B.C.D. नाड्योर्कौ
b. A. दयाश्चन्द्रं; B. देयाश्चन्द्रं; (B2. °श्चन्द्र)
C. दयतस्तत्कला विधोःशोध्याः । D. दयाच्चक्रा-
धोनिन्दुरविविवरात्
A. समेदुरविवरा; B. यमेन्दुरविवरा
c. A. नृवशुद्रवाच्च शोध्या; B. स्यु-द्भवाब्धः शोध्याः;
C. See above; D. पाण्डवघ्नाश्च शोध्याः
d. A. तत्कालशशिदिनसार्द्धे शशिलिप्तः ।
c-d. C. स भवति तत्कालशशी दिवसैष्ये लिप्तिकायुक्तः;
D. शशीलिप्तः

idea. NP insert *vi* to get the reading *ravi-vivarāt* but leave the other errors untouched or making unwarranted emendations.

[चन्द्रग्रहणसम्भवः]

राहोः स'षट्कृति'कलां हित्वांशं तच्छशाङ्कविवरांशैः |
ग्रहणं त्रयोदशान्तः पञ्चदशान्तस्तमस्तस्य || २ ||

Probability of an eclipse

2. Deduct one degree and thirty-six minutes from Rāhu's Head or Tail (whichever is near the Moon) and find the interval in degrees between that and the Moon (at full moon found above). If it is less than thirteen, a lunar eclipse will occur then. If it is less than fifteen, (and above thirteen), there will only be a slight darkening.

The following is the explanation: At the moment when the distance between the centres of the Moon and the Shadow circle is equal to the sum of their semi-diameters there is the first contact or the last contact of the eclipse, because the rims just touch each other then. see Fig. 1a, below.

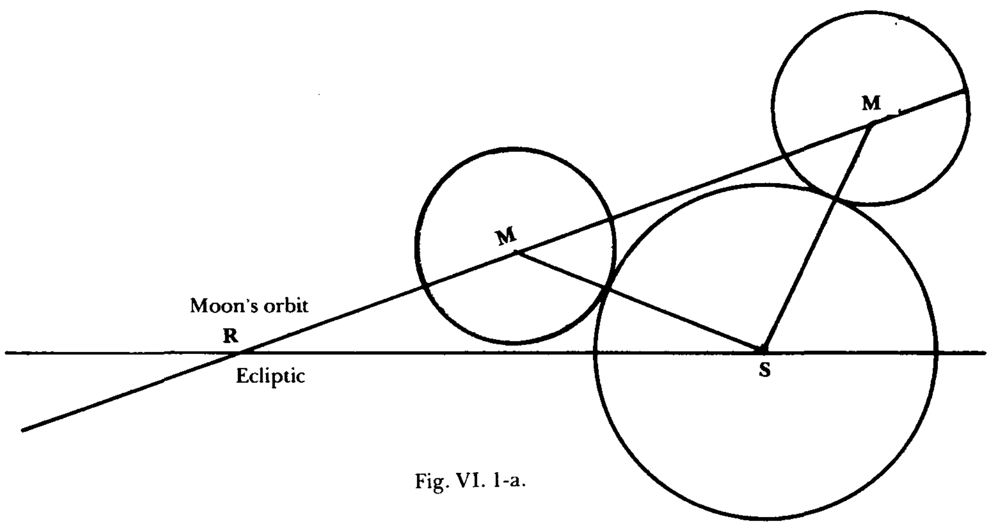


Fig. VI. 1-a.

The centre of the Shadow is always six *rāśis* distant from the Sun. At full moon (i.e. the end of the *tithi*) the Moon projected on the ecliptic (i.e. the longitude of the Moon) is 6 *rāśis* distant from the Sun, as we have already said. Therefore the centre of the Shadow also is there. But the actual Moon

2a. B. सषट्ततिकलां (B2. वांशं, B3. चाशं°)
b. A2. हिचांशं (A1. हित्वांशं); B. हिपाशंतष्ठांशक
d. A.B. °दशान्तःस्तमस्तस्य (B. °न्तःस°)

is on its orbit, at a distance equal to its latitude. Therefore only when the latitude is equal to the sum of the semi-diameters, is there at least a grazing of the rims[1]. (See Fig. 1b)

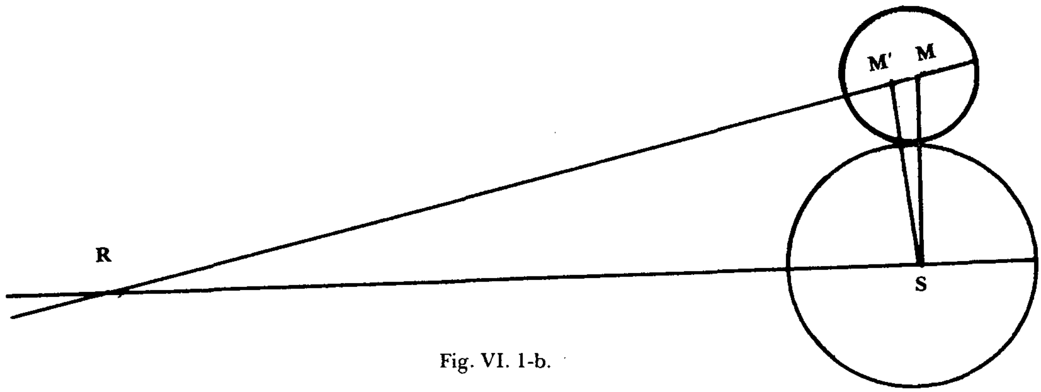


Fig. VI. 1-b.

As according to the *Pauliśa* the sum of the semi-diameters is always 55′, (this will be shown later), and as this much latitude can be got only if Moon ~ Rāhu is 13°, and not more[2] there can be no eclipse, if Moon ~ Rāhu is greater than 13°.

As for the little darkening from 13° to 15°, it is due to the Moon entering the penumbra alone and getting out, instead of entering the umbra. It is well-known that if the source of light is not a point, there is a region not so dark round the shadow, which is darker and darker as the shadow is approached, and becomes sufficient to be seen. This *Siddhānta* has taken this region to be about 8′, round the shadow. Therefore, the Moon's orb will touch this region at full moon if the latitude is 63′, and for this its distance from Rāhu must be 15′, as given here.

As for deducting 1° 36′ from Rāhu, the author has found this is necessary by observation, and we have to accept it, as agreement with observation is necessary, otherwise people will lose faith in the *Śāstra*. Or the *Pauliśa Siddhānta* itself gives this correction for agreement with observation, for, in the phenomena intended to be seen, such correction is the practice of the writers of this *Śāstra*. But it may be asked how this need for correction arises at all. This implies that either the longitude of Rāhu or that of the Moon is incorrect. We showed in ch.III that at epoch Rāhu-head was 235° 59′

1. What we have said here is a little inexact and taken as such by most of the ancient authors. Actually, since the Moon's orbit is inclined to the ecliptic by about 5°, the minimum distance between the Moon and the Shadow, given by SM′, the perpendicular on the orbit from S, is a little less than SM, and it is only when SM′ is equal to the semi-diameters that the grazing occurs. Therefore even if the latitude at full moon is a little greater, an eclipse can occur, but this has been neglected as being very small, actually less than a quarter of a minute of arc.

2. As explained by us under III.31, taking 380′ as the maximum latitude (i.e. for 90° distance), and taking the latitude as proportionate to the *Bhuja* of Moon-Rāhu, as given by the *siddhānta* there, we get 380′ × 13° ÷ 90° = 55′, for Moon ~ Rāhu equal to 13°. This agreement here is the proof of the correctness of what we said above in the explanation that the latitude is proportionate to the degrees of *Bhuja*. If we take the maximum latitude to be 280′, as given by the reading of the text there, or to be 270′ as TS have taken there without assigning any reason, neither taking the latitude as proportionate to the degrees of Moon ~ Rāhu, nor correctly as proportionate to sin (Moon ~ Rāhu) will give 55′. This is the reason why TS themselves have, in this section, in verse 5, abandoned both 280′ and 270′, and taken 240′ as the maximum latitude. (vide their Sanskrit and English explanations under VI.5.).

according to the *Pauliśa* and this agrees beautifully with its position than according to modern astronomy, 236°, and tolerably well with those of other *Siddhāntas.* Therefore the incorrectness must be in the Moon, and as much error in the *tithi* is unlikely, nor in the Sun as well. On examination we find it is indeed so; we find that at the period of the author the Sun and the Moon of *Pauliśa* were less by about a degree and a half, than those of other *Siddhañtas*. By this error in the Moon, the value of Moon minus Rāhu will be less by about a degree and a half, (1° 36′) and instead of correcting the error by adding it to the Moon, we subtract 1° 36′ from Rāhu, which is the same. We do not add it to the Moon, because if we do, we must add the same quantity to the Sun to keep the *tithi* intact, and this will affect the *Samkramaṇas,* and thus cause a lot of disturbance. If added to Rāhu nobody will even notice it. It may be asked whether it is not wrong to use the latitude calculated in III.31 from uncorrected Rāhu in our work here, as we are going to do. Indeed it will be wrong, and that is why the author gives a correction below, in stanze 4, to set it right.[1]

TS do not understand the nature of this correction, not even its amount and its connection with stanza 4. Their ignorance in the matter of the computation of Rāhu, which we exposed in III. 28-29, they exhibit here also, (see their Sanskrit Comm. page 40).

[ग्रहणस्थितिकालः]

विक्षेपकलाकृतिवर्जितस्य पञ्चोनषष्टिवर्गस्य |
मू(लं) द्विगुणं तिथिवद्विभज्य काल(: स्थि)तेर्भवति || ३ ||
शशितिमिरविवरभा(गाः) त्रयोदशोनाः शराऽऽहताः क्षेप्याः |
स्थि(त्यां) विनाडिकास्ता राहावधिकेऽन्यथा हानिः || ४ ||

Duration of the eclipse

3. Square the Moon's latitude, subtract it from the square of 55, (i.e. from 3025), and find its square root. Double this, and multiplying by 60, divide by the difference of the daily motions of the Sun and Moon, in minutes. The approximate time of the duration of the eclipse is got in *nāḍis.*

4. If Moon ~ Sun is less than 13°, multiply the degrees by 5. The result are *vināḍis*. Add these *vināḍis* to the duration if the longitude of Rāhu is greater than that of the Moon, and subtract if the Moon is greater than Rāhu. Thus the time of duration becomes correct.

The following are the steps in the work:

i. Using III.31, find the Moon's latitude, (using uncorrected Rāhu).

ii. Uncorrected time of duration in *nāḍis* = $\sqrt{3025 - (\text{latitude in minutes})^2} \times 120 \div$ difference of daily motions of Sun and Moon in minutes.

3a. A.क्रति
c. A.B.मूलो
d. A.B.कालस्थि

4a. A.B.C.D.भागैः
c. A.B.C.D.स्थित्या

iii. Corrected time of duration = uncorrected time ± 5 × degrees of Moon ~ Rāhu in *vināḍis* (If Rāhu is greater use the upper sign, if less use the lower sign. Moon ~ Rāhu is what we get in verse 2, in this section).

Example 1. On a day, at sunset, the longitude of the Sun is rā. 10-10-12, longitude of the Moon rā. 4-8-57, Sun's daily motion 60′ and Moon's daily motion 810′. (From these the end of the full moon tithi falls at 6 nāḍis after sunset). The Tail of Rāhu at full moon is rā. 4-7-42. Examine whether a lunar eclipse will occur, and if so, find the duration.

As a preliminary, the Moon at full moon should be found by verse 1, thus: The time to elapse after sunset, for full moon, is 6 *nāḍis*. Adding 6′ to the Sun at sunset, the Sun at full moon is *rā.* 10-10-12 + 6′ = *rā.* 10-10-18. Therefore the Moon is *rā.* 4-10-18.

Now, examine whether there will be an eclipse. Rāhu at full moon = *rā.* 4-7-42 (given). Corrected Rāhu = *rā.* 4-7-42 − 1° 36′ = *rā.* 4-6-6. Moon ~ corrected Rāhu = 4° 12′. As this is less than 13°, there is eclipse.

Now for the work of getting the duration:

i. The Moon's latitude (supposed known already) = 380′ × (*rā.* 4-10-18 −*rā.* 4-7-42 in degrees) ÷ 90° = 11′.

ii. Uncorrected duration in *nāḍis* = $\sqrt{3025 - 11^2} \times 120 \div (810 - 60) = \sqrt{2904} \times 120 \div 750$ = *nā.* 8-37.

iii. Corrected duration = *nā.* 8-37 − 5 × 4.2 *vināḍis* = *nā.* 8-16. (subtraction because Rāhu is less than the Moon).

The following is the rationale of the procedure: We have said that, according to the *Siddhānta*, when the distance between the centres of the Shadow and the Moon is 55′, the eclipse begins or ends, because at these times the distances are equal to the sum of the semi-diameters.

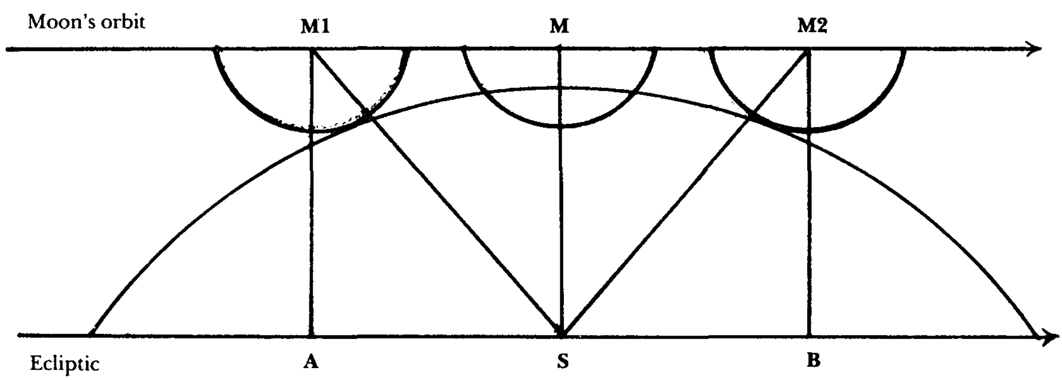


Fig. VI. 2

See SM_1 and SM_2 in Fig 2, where S is the Shadow and M_1, M_2 are the Moon. At full moon, the latitude is the distance between the centres, at that time. (SM), because at full moon the centre of the shadow is at S, because it is always 6 *rāśis* distant from the Sun. Since the inclination of the orbit to the ecliptic is small, the *siddhānta* takes it that the orbit and the ecliptic are practically parallel, and that the latitudes of the Moon at first contact (AM_1) at full moon (SM), and at last contact (BM_2) are

equal. As the three lines of latitude are perpendicular to the ecliptic, $\triangle M_1 AS$, and $\triangle M_2 BS$, are equal and right angled at A and B. Therefore AS = SB = $\sqrt{(\text{sum of semi-diameters})^2 - \text{latitude}^2}$ = $\sqrt{55^2 - \text{lat}^2}$, where AS or SB are the difference of the Moon's longitude at first or last contacts from its longitude at new moon, and measured in minutes of arc. As the motion of S is the same as that of the Sun, the time taken by the longitude to move from A to S or from S to B = the minutes of difference ÷ the difference of the motions of the Sun and the Moon in minutes = $\sqrt{55^2 - \text{lat}^2} \times 60 \div$ difference of daily motion in minutes, in *nāḍis*. Therefore the total time in *nāḍis* from A to B (this is the uncorrected whole duration) $= 2 \times 60 \times \sqrt{55^2 - \text{lat}^2} \div$ the difference of daily motions in minutes.

But actually the latitudes at the first and last contacts differ enough from that of the full moon to justify the use of their exact value. So each should be used separately, and the half-duration before full moon, and that after full moon should be found. Using the latitudes of these times again, if necessary, they should be found again. Certain *Karaṇas* (manuals) like the *Vākyakaraṇa* apply a certain correction in the place of this repetition of work. This correction depends upon the Moon ~ Rāhu at full moon, like the correction in stanza 4, given by the author for correcting the duration, and therefore it is possible that the correction for the difference in latitude has been included in that correction. But as the correction given is rough, we cannot analyse it and find out whether the author has done so or not.

Let us now consider the rationale of the correction in stanza 4. We have already hinted that this is to compensate for using the latitude got in III.31 from uncorrected Rāhu, instead of that from corrected Rāhu, which is to be used in our work here.

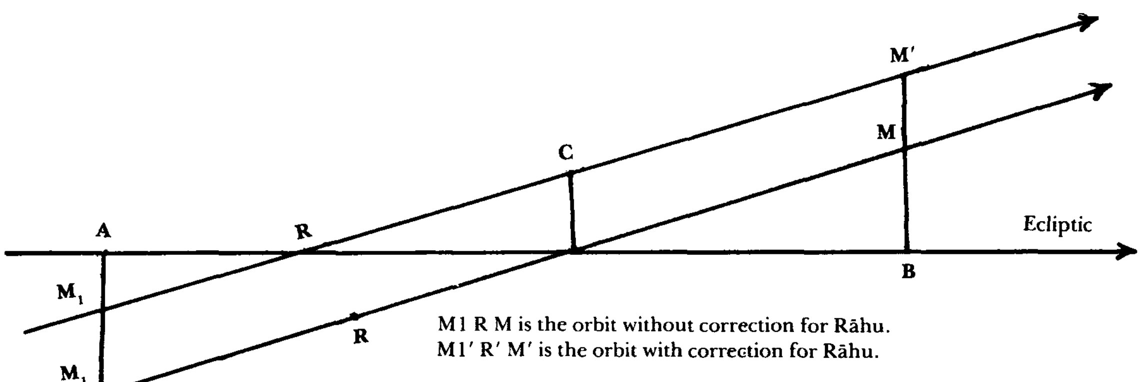


Fig. VI. 3

In Fig. 3, *R* is the uncorrected position of Rāhu, and *R'* is its corrected position. The distance between them is 1° 36', given in stanza 2. When the Moon is greater than Rāhu, (M, M') then its uncorrected latitude is MB, and the corrected latitude is M'B, greater by M'M. This is case I. When the Moon is less than Rāhu (M_1, M_1'), then the uncorrected latitude is M_1A, and the corrected latitude is $M_1'A$, less by M_1' M_1. This is case II. In case I, if the uncorrected latitude, which is less, is used in the work, $\sqrt{55^2 - \text{lat}^2}$ will be greater than what it should be, and the duration should be lessened by a correction. Therefore it is said that the correction is subtractive when the Moon is greater than Rāhu. In case II, since the uncorrected latitude is greater, $\sqrt{55^2 - \text{lat}^2}$ will be less than what it should be, and so it is said that the correction is additive if the Moon is less than Rāhu, *i.e.* if Rāhu is greater. The Fig. is for Rāhu-Head. It can be seen that at Rāhu-Tail too the same holds.

We can show this by theoretical considerations as well, thus: Rāhu lessened by 1° 36′, is equivalent to Moon increased by 1° 36′, in its effect on Moon – Rāhu. The latitude is proportionate to the distance of the Moon from Rāhu in each quadrant. In the first and third quadrants, the Moon is greater than Rāhu, and the increase in the Moon by the correction increases the latitude. In the second and fourth quadrants, the Moon is less than Rāhu, and the increase in the Moon by the correction lessens its distance from Rāhu, with the result that the corrected latitude is less. Thus for Moon greater than Rāhu the correct latitude is greater, and for Moon less, it is less. The rest is as we have shown already.

Now we shall find the quantity of correction: As the angles at R and R' are equal, the corrected and the original orbits are parallel. (see the Fig.) Therefore the differences in the latitudes at any position like M'_1 M_1, M′M, and C R are equal. But C R, being the latitude caused by 1° 36′ of longitude, is equal to 380′ × 1° 36′ ÷ 90° = 6¾ minutes of arc. Therefore the difference in any position is 6¾′.

We shall first see how much difference this will produce in the half duration measured in minutes of arc. Clearly it is $= \sqrt{55^2 - (\text{lat} \pm 6\tfrac{3}{4})^2} - \sqrt{55^2 - \text{lat}^2}$

$= \sqrt{55^2 - \text{lat}^2 \mp 13\tfrac{1}{2}\,\text{lat}} - \sqrt{55^2 - \text{lat}^2}$, (if $6\tfrac{3}{4}^2$ is neglected, being small in comparison with 55^2.)

$= \sqrt{55^2 - \text{lat}^2}\sqrt{1 \mp 13\tfrac{1}{2}\,\text{lat}/(55^2 - \text{lat}^2)} - \sqrt{55^2 - \text{lat}^2}$

$= \sqrt{55^2 - \text{lat}^2}\,\{1 \mp 13\tfrac{1}{2}\,\text{lat}/2(55^2 - \text{lat}^2)\} - \sqrt{55^2 - \text{lat}^2}$ (if higher powers of $13\tfrac{1}{2}\,\text{lat}/(55^2 - \text{lat}^2)$) are neglected.

$= \mp 13\tfrac{1}{2}\,\text{lat}/2\sqrt{55^2 - \text{lat}^2}$, and the author has neglected lat^2 and taken this as $\mp 13\tfrac{1}{2}\,\text{lat}/2 \times 55$.

Using the difference of the mean daily motions of the Sun and the Moon, because this will not matter in the already rough result, and doubling for the whole duration, the *vināḍis* of correction are, 13½ lat × 2 × 60 × 60 ÷ (2 × 55 × 720)

= 13½ × lat × 5/55 = 13½ × {(Moon ~ R)° × 55/13°} × 5/55 (since lat = Moon ~ Rāhu)° × 55/13°,)
= 5 × (Moon ~ Rāhu), roughly, as given here.

The greater the latitude, the greater the roughness, but this will be submerged in the roughness caused by several other things like the incorrect semi-diameters etc., but the method has the advantage of being easy to apply.

We shall consider the readings now. In verse 3, the need for correcting *mūlaḥ* into *mūlaṃ* and *kālasthiteḥ* into *kālaḥ sthiteḥ* will be clear, as also for *sthityā* into *sthityām* in verse 4. As for correcting *bhāgaiḥ* into *bhāgāḥ*, this is justified by what we have shown in the explanation, *viz.* that it is Moon ~ Rāhu that is to be multiplied by 5 to give the *vināḍis* of correction. If the word *bhāgaiḥ*, is taken as it is, the instruction should be taken to mean "five multiplied by the difference of Moon ~ Rāhu and 13°. By this, the correction, instead of being zero, as it should be for zero latitude, is the maximum of 65 *vināḍis*. Instead of being the maximum for maximum latitude, the correction becomes zero. Further, on both sides of zero latitude, where there is a transition from the Moon being greater, to Rāhu being greater, there is a jump from − 65 *vināḍis* to + 65 *vināḍis*, which itself is an indication that the formula is incorrect. But it may be objected that if our correction into *bhāgāḥ* is accepted the word *trayodaśonāḥ* serves no purpose, for the computation will be begun only if the difference is less than 13°, and therefore this need not be mentioned. The answer is this: From our explanation of the formula for correction it may be seen that it is applicable if the difference is

13°, and even a little more. The author instructs that the correction should be applied only if the difference is less than 13°.

But TS (also NP), have taken the word *bhāgaiḥ* as it is and given the interpretation, because they do not know the nature or the rationale of the correction. Here, Thibaut alone says (vide page 43 of Eng. Translation): "To the duration so found stanza 4 directs us to apply a correction whose rationale we are however unable to assign", and thus accepts ignorance. But S. Dvivedi in his Sanskrit Commentary says that the Moon's motion varies from time to time, and this correction is to rectify the error due to the variation. He is unable to see that the variation of the Moon's motion has nothing to do with the correction here, and cannot be related to it.

[विमर्दकालः]

किन्त्वन्तरांशहीनैः पञ्चभिरूना हता दश 'कृत'घ्नाः |
तत्पदमेकाश्विघ्नं प(ञ्चां)शोऽस्माद् विमर्दकलाः || ५ ||

Total obscuration

5. Deduct the difference of the longitudes between the Moon and Rāhu from five degrees. Deduct this from ten degrees, and multiply the remainder by this itself and by four. Find the square root of the result and multiply it by 21. The minutes of arc of total obscuration is got. This dividend by the daily motion gives the time.

The rule given is as follows: Minutes of obscuration = $21 \times \sqrt{\{5 - (\text{Moon} \sim \text{Rāhu})\}\,[10 - \{5 - (\text{Moon} \sim \text{Rāhu})\}] \times 4}/5$.

This can be simplified as: Minutes of obscuration = $2 \times 21 \sqrt{5^2 - (\text{Moon} \sim \text{Rāhu})^2}/5$.

$= 2 \times 21 \times \sqrt{25 - (\text{Moon} \sim \text{Rāhu})^2}/5$.

This multiplied by 60 and divided by the daily motion gives the duration of obscuration in *nāḍikās*.

Here, 21 × (Moon ~ Rāhu)/5 is the Moon's latitude at full moon. The latitude according to the *Pauliśa* has been shown to be (Moon ~ Rāhu) × 380′/90, where Moon ~ Rāhu is in degrees. As 380/90 is very nearly equal to 21/5, we can say:

Latitude in minutes = 21 × (Moon ~ Rāhu)/5.

It must be noted that we use here the corrected Rāhu to get Moon ~ Rāhu. So, the latitude obtained is the correct latitude. Therefore, no correction is necessary here corresponding to that of verse 4, above.

Now, the rule is explained thus: In this *Siddhānta*, the difference between the semi-diameters of

5a. B. कि चंतराशहीनैः (B3. कि चतय रा०)
b. B1. पञ्चाभी. B. हता द om श. A. क्रतघ्नाः
c. B. om घ्नं
d. A.B. पञ्चाशो

the Moon and the Shadow is 21 minutes of arc. Therefore, when the difference between their centres is 21′, the total obscuration begins or ends, as at M_1 or M_2 in Fig. 4, below.

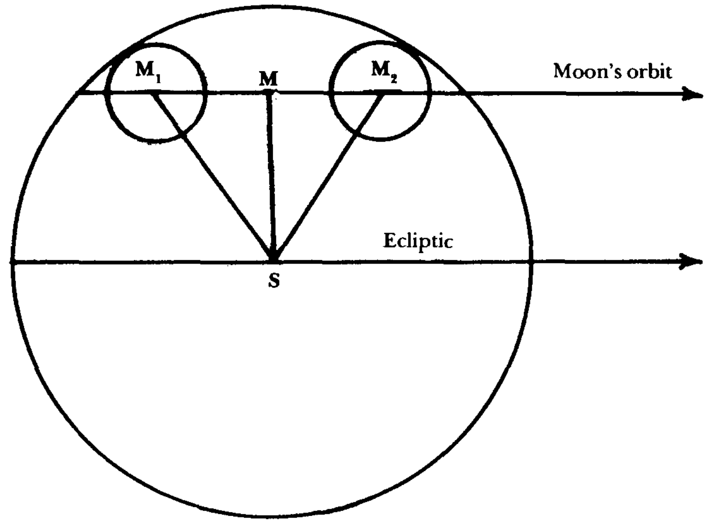


Fig. VI. 4

Here M is the Moon at new-moon, and S is the centre of the Shadow. $M_1S = M_2S = 21'$ = the difference of the semi-diameters, constant according to this *Siddhānta*. SM is the latitude at full moon. Therefore,

Minutes of obscuration = $M_1M_2 = 2(M_1M$ or $MM_2)$
$= 2\sqrt{SM_1^2 - SM^2} = 2\sqrt{21^2 - \text{latitude}^2}$
$= 2\sqrt{21^2 - \{21 \times (\text{moon} \sim \text{Rahu})/5\}^2}$
$= 2 \times 21\sqrt{5^2 - (\text{moon} \sim \text{Rāhu})^2/5}$,
$= 2 \times 21 \times \sqrt{25 - (\text{moon} \sim \text{Rāhu})^2}$, the simplified rule, from which by inverse operation, we get the original rule, $21 \times \sqrt{\{5 - (\text{moon} \sim \text{Rāhu})\} \times [10 - \{5 - (\text{moon} \sim \text{Rāhu})\}]}\ 4/5$.

The conversion of the minutes of arc of obscuration into time is, as already given, by the proportion, Minutes of daily motion of (Moon – Sun): Minutes of obscuration :: 60 *nāḍikās:nāḍikās* of obscuration.

From the simplified rule it will be readily seen that when Moon ~ Rāhu is 5°, the minutes of obscuration, and thence the time, is zero. Therefore only when the difference is less than 5°, there is obscuration, not when greater, *i.e.* if the correct latitude at new moon is greater than 21′, there is no total eclipse.

Example 2. The Moon at new moon is rā. 8-13-24. Rāhu (Tail) is rā. 8-12-0. The daily motion of (Moon – Sun) = 750′. Find the minutes of obscuration and the time.

The corrected Rāhu = *rā*. 8-12-0 – 1° 36′ = *rā*. 8-10-24
Moon ~ Rāhu = *rā*. 8-13-24 – *rā*. 8-10-24 = 3°.
By the simplified rule, the minutes of obscuration = $2 \times \sqrt{25 - 3^2} \times 21/5 = 2 \times 4 \times 21/5$, minutes.

The duration of obscuration = $2 \times 4 \times 21 \times 60/(5 \times 750)$ = *nā*. 2-41.

From verse 3, giving the general duration, we see that the sum of the semi-diameters of Shadow and Moon is 55′. Here we see that their difference is 21′. Hence, (55′ + 21′) = 76′, is the diameter of the Shadow according to this *Siddhānta*, and 55′ − 21′ = 34′, is the diameter of the Moon, giving the semi-diameters as 38′ and 17′ respectively.

By a strange confusion of ideas TS and NP have concluded here that when Moon ~ Rāhu is less than 10°, there must be a total eclipse. (vide the Sanskrit com.p.33, and English translation, p.44, NP, Pt. II, p.53). We have shown that for a total eclipse to occur the difference must be less than 5°. It is easy to see which is correct. If the difference is greater than 5°, the number under the radix becomes negative, and no real root can be obtained. For e.g. if we take 7°, as the difference, according to TS there must be total obscuration. But using it in the formula, we get,

$21 \times \sqrt{(5-7)\{10-(5-7)\}\,4/5} = 21\sqrt{-96/5} = 21 \times 4\sqrt{-6/5}$,

which does not give a real value. Their error is due to their confusing in their work, the 21 minutes, sine of 10°, as 21 minutes, latitude to be got for 10° difference.

Further the postulation by TS of a maximum latitude of 240′ in this context is unwarranted. True, from the above a latitude of 55′ for 13° difference, and 21′ for 5° difference will follow, if the correct formula, with the sine of (Moon ~ Rāhu) is used, instead of the degree of difference. But nowhere in Hindu astronomy is 240′ given, and the *Vāsiṣṭha* does not give the latitude at all. So when the *Vāsiṣṭha* wants the latitude to be used in V. 3, we have got to use only the *Pauliśa* formula, and the reading gives 280′, which TS have translated tacitly as 270′. 280′, if taken, will give 63′ and 24′ for differences 13° and 5°, and 270′ will give 61′ and 23′, instead of 55′ and 21′, both of which are unsupported by the context. This is the reason why we changed the reading to mean 380′, instead of 280′, and, following the instructions strictly, gave the rule, latitude = 380′ × difference in degrees/90, getting 55′ and 21′ for differences of 13° and 5°. This is also in keeping with the practice of the *Pauliśa*, which usually uses for proportion the degrees in the place of sines.

[स्पर्शमोक्षदिशौ]

स्थितिदलविमर्ददलयोर्विशेष(के तमः) सकलमत्तीन्दुम् |
प्रग्रहणमोक्षशशिराहुविवरभागैश्च दिग् वाच्या || ६ ||

विक्षेपविपर्यासान्तरीयभागे (कृ)ते त्रयोदशधा |
परिधौ प्राक्प्रभृतीन्दोर्ग्रहणा(शां)शे वदेत् पर्व || ७ ||

शशिपरिधिदला(र्ध)घ्ने खेन्द्वन्तरभागसंगुणे (चा)क्षे |
'खखरूपाष्ट' हृते प्राग्वल(नं) वामं च्युते सव्यम् || ८ ||

Direction of the eclipse

6. During the interval from the time of first contact to the beginning of totality, Rāhu (i.e. darkness), swallows the Moon completely. The directions of the points of first and last contacts are to be calculated from the Moon ~ Rāhu of those times.

7. Divide the semi-orb of the Moon situated opposite to the direction of latitude into 13 parts, by straight lines parallel to the east-west diameter, at

equal distances from one another. At the part of the rim equal to the degrees of Moon ~ Rāhu, on the eastern or western part of the orb, are the points of first and last contacts, from which the directions can be read.

8. Multiply a fourth of the Moon's rim, (in whatever unit taken, as for e.g. minutes or digits) by the latitude, and again by the degrees of the Moon east or west of the meridian. Divide this by 8100. By so many units is the east or west point of contact bent northward or away from the north respectively if the Moon is east of the meridian, and bent away from the north and northward respectively, if the Moon is west of the meridian.

The instructions to obtain the directions of the points of contact have been explained by figures 5 a, b, c.

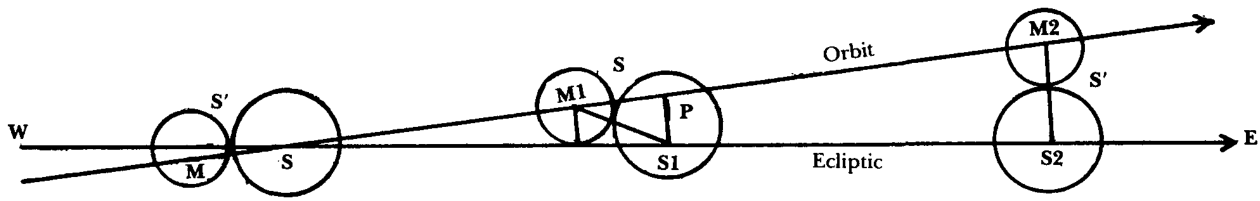


Fig. VI. 5-a.

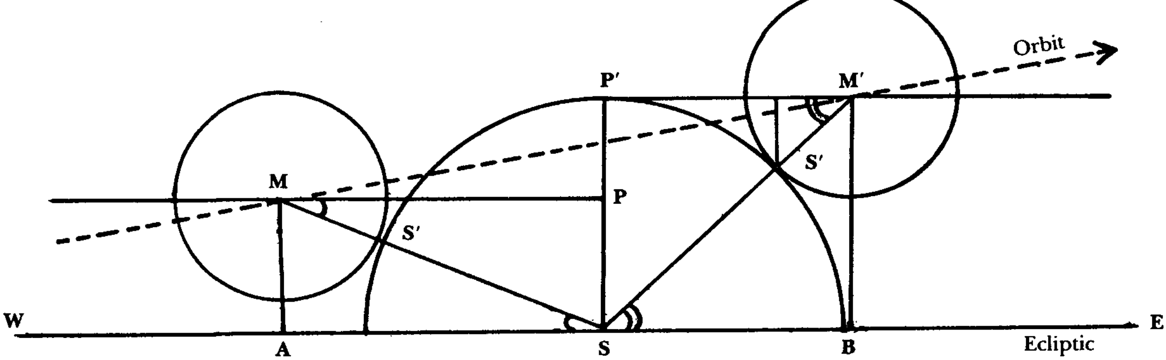


Fig. VI. 5-b.

6a. A. स्थिदल
b. A. विशेषको मे; B. विशेषका मे; C. विशेषके तमः; D. विशेषकाले
A. सकलीमतीत्तींदुं; B. सकलमतीन्दुः (B3. ०न्दुं); D. ऽसकलं तमोऽत्तीन्दुम्
c. A. प्रग्रहमोक्ष; B1.3. प्रग्रहमा क्ष; C.D. प्रग्रहमोक्षे
7a. C. विपर्यस्ता; D. विपर्यासः
b. C-D. तुरीयभागे
A. क्रते च यो; B. तते च यो; D. हते. A2. ०दशघ्न
c. A1. परिघ्मे; A2. परिधौ
d. A. ग्रहणास्तांशे; B. ग्रहणा स्वांशे; D. ग्रहणाशा (तद्) वदेत् पर्व
8a. A.B. ०दलाद्विघ्ने
b. A.B. वाक्षे
c. B. रूपाष्टद्भते
d. A.B. वलनावामं युते (B. च्युते); D. वामं परे सव्यम् ।

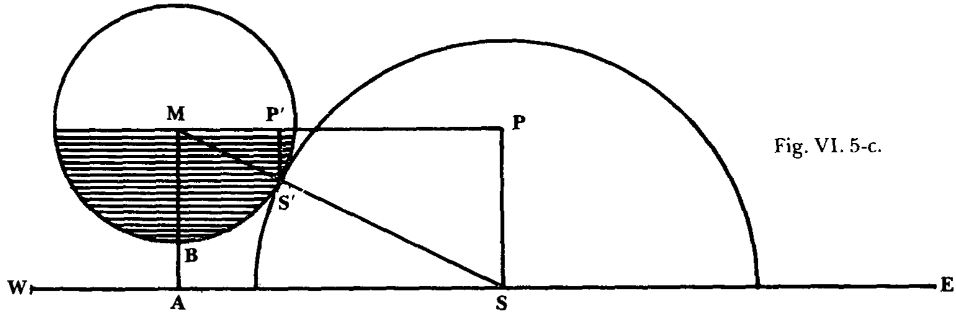


Fig. VI. 5-c.

In all the three figures, M, M_1, M_2, M′ represent the centres of the Moon, and S, S_1, S_2, the centres of the Shadow. S′ is the point of contact. *R* is Rāhu. In fig. 5a, *R* M_2 is part of the Moon's orbit, and RS_2 is part of the ecliptic. In position S_2 which is the limit for the occurrence of an eclipse, MS_2 = 13°, and M_2S_2 is the latitude, equal to 55′, = the sum of the semi-diameters, i.e., $M_2S' + S'S_2$. S′, the point of contact, is seen 90° from the east point, directed towards the north from the ecliptic, i.e. at the north point of the Shadow, but at the south point with reference to the Moon. In position S, the Moon is at the node, Rāhu, and (Moon ~ Rāhu) is 0°. Clearly, S′, the first point of contact, is at the east point. In position S, between the above two, it is seen that S′, the first point of contact, makes an angle P M_1 S_1 with the east point, on the south, with reference to the Moon.

It may be seen that the sine of the angle is proportionate to PS_1, the latitude, which itself is proportionate to (Moon ~ Rāhu) as we have shown. Thus, at any intermediate position, the point of contact makes an angle with the east, whose sine is proportionate to Moon ~ Rāhu. Hence the rule to divide the Moon's half opposite to the direction of the latitude into 13 parts by parallel lines at equal intervals, and take the point of contact of that line which corresponds to the degrees, Moon ~ Rāhu. This is shown clearly in fig. 5c. Here P′ S′, the sine of the angle P'MS', which is the direction, is seen proportionate to PS, the latitude, which is proportionate to Moon ~ Rāhu. The figure is for Moon ~ Rāhu equal to 7°.

Fig. 5b is intended to show both the first and last points of contact, and because of the increase (or decrease) of the latitude during the interval, there is an increase (or decrease) in the angle. In the figure, the angle of first contact, P'MS', corresponds to the latitude MA and is smaller; the angle of last contact, P'M'S' corresponds to the greater latitude M'B, and is greater. It is also to be noted that the last contact is at the western part of the Moon, the Moon now being east of the Shadow.

The directions mentioned above are with reference to the ecliptic, taking it as east-west, (neglecting the angle of inclination of the Moon's orbit). But the directions have to be given as seen by the observer. For this, two corrections have to be applied, one to convert it with reference to the east-west of the equator, called *Āyana-valana*, and the other to correct it for the east-west of the place. depending on the latitude of the place, called the *Ākṣavalana*. Both these have been mentioned and explained in connection with the observation of the first appearance of the moon given in Chap V. The author here gives the *Ākṣavalana* alone following the original *Siddhānta*, neglecting the other one, though that is not negligible. Even in this, he takes into consideration only the northern hemisphere. There the celestial equator is inclined south. An observer facing east looking at a body on the celestial equator sees the east point bent northward, and the west point bent southward. Similarly, an observer facing a body west, sees the east point bent south, and the west point bent north.

The directions are changed accordingly. (For illustration see fig. 7, below given under example 3). All this has been explained in chap. V. The *Siddhānta* takes it that the bending is proportionate to the latitude, being zero at the equator and 90° at the pole. So, in terms of the length of the circumference, the bending = (latitude/90°) × circumference/4. But this amount of bending is only at the horizon. On the meridian there is no bending. In between, the *Siddhānta* takes it as proportionate to the angle of the Moon from the meridian. Thus,

Bending = (latitude/90°) × (circumference/4) × (degrees of the Moon from the meridian/90°)
= quarter circumference × latitude × degrees of the Moon from the meridian/8100, as given.

As for the Moon being "devoured", it is a figurative expression, the Shadow being identified with the demon, Rāhu, in the Purāṇas.

In saying that Moon ~ Rāhu should be done once for finding the point of first contact, and again for the last contact, the author recognises that the difference may be considerable, and thereby indicates that it will be good if the times also are computed separately, using the different latitudes. But TS and NP by their emendation, *pragrahamokṣe,* have shut out all this suggestion.

TS do not seem to understand why the division into thirteen parts is instructed to be made, for Dr. Thibaut says, "We do not know the reason for the direction, given in stanza 7, to divide each quarter of the circumference into thirteen parts." (p.45). It is not each quarter, and it is not the quarter-circumference that is to be equally divided.

We have emended *grahaṇāsvāṃśe* into *grahaṇāśāṁśe,* whereby we understand that the point of contact is at the point where the parallel line corresponding to Moon ~ Rāhu meets the circumference. The emendation *grahaṇāśā 'tad' vadet* by NP is not warranted. In the matter of the directions of *Ākṣavalana,* Thibaut says the opposite of what Sudhakara Dvivedi says, and neither gives the correct direction. (vide. Com. and Translation)

[ग्रहणकालः वर्णं च]

[तिथ्यन्ते ग्रहमध्यं प्राक् परतः स्थितिदलेन चाऽऽद्यन्तौ ।
रक्तकपिलौ च वर्णावुच्चाऽधस्स्थे परे नितराम् || ८A ||]
सर्वग्रासिन्येवं वर्णविशेषं वदेन्निशानाथे |
उदयास्तमये धूम्रं खण्डग्रहणे (सलिलदाभम्) || ९ ||
राहुमुखोनं चक्रं [धीद्वियम]गुणं शशाङ्कसंयुक्तम् |
(जूकेत्थगेऽयमुच्चः) क्रियादिकन्यान्त(गे) नीचः || १० ||

Moment of the eclipse and its colour

8A-9. The middle of the eclipse is at the moment of new moon. The times of first and last contacts are earlier and later than the middle, by half the time of duration. When the eclipse is total, the colour of the Moon is red or brown as it is farthest or nearest to the earth, respectively, and mixed, more or less, in between. When the eclipse is near sunset or sunrise, the Moon is smoky in colour. When the eclipse is partial, the Moon has the colour of raincloud.

10. Subtract the Head of Rāhu from 12 *rāśis*, multiply it by 228, and add the Moon's longitude. If this is between 6 and 12 *rāśis*, the Moon is farther, and if between 0 and 6 *rāśis*, it is nearer. (The idea is, that the nearer this sum is to 9 *rāśis*, the farther is the Moon and its colour at total eclipse is nearer to red. The nearer this sum is to 3 *rāśis* the nearer is the Moon, and its colour is nearer to brown).

Since this *Siddhānta* uses the latitude, (or Moon ~ Rāhu) at full moon to find the duration, the part of the duration before full moon is equal to that after full moon, and the middle is at full moon. But other *siddhāntas* repeat the work, using the latitudes at first and last contacts separately, so that the two parts are not equal, and the middle does not occur at full moon. Still all *siddhāntas* technically call the moment of full moon as the middle, since at that time the eclipse is practically the maximum.

As for the colour of the Moon at eclipse, it is based on observation, and given slightly differently by different *Siddhāntas*. Some take the fraction of the Moon eclipsed as the criterion for the colour, others the time of the eclipse and its nearness to sunset or sunrise, etc. Here, this *Siddhānta* uses, in addition, a new criterion, not given by any other *Siddhānta*, *viz.* the distance of the Moon from the observer, and there is truth in what the *Siddhānta* says.

Here, it may be asked how at all is it possible for the Moon to have any colour at eclipse. It is an opaque body, and what illumination it has comes from the Sun's rays falling on it. When it is immersed in the Sun's umbra, i.e. full shadow, (we consider the Moon in umbra alone as eclipsed, and not in pen-umbra), the Sun's rays cannot fall on it. It cannot be the earth-shine falling on the Moon and dimly illuminating it, as in the crescent Moon, giving rise to the popular belief of "the old Moon in the arms of the new". At times of new moon, when the lunar eclipse occurs, there is no earth-shine opposite the Moon to illuminate it. This is the answer: Though the Moon is in the earth's shadow geometrically speaking, the Sun's rays, refracted by the earth's atmosphere, fall on the Moon and illuminate it with a red or brown glow, red light alone being able to reach the Moon after passing through the long section of the earth's atmosphere undispersed, on account of its greater wave-length. (See fig. 6).

8A.9. Quoted by Utpala on *BS* 5.18

8A. Om both in A and B, but included in this edition on account of its essentiality in this context and its being quoted as a verse of VM by Utpala in continuity with verse 8.

While C omits this verse since it is not available in the text mss. D adds it. (as no. 9, and the further verses numbered as 10 etc.) since Utpala has it.

9a. A. पर्वग्रासिन्येवं; C. ग्रासे पीनं
D. numbers the verse as 10 and the verses 10-14 as 11-15.

c. A.B. उदयास्तगांसधूम्रं (b. धूम्र); C. उदयास्तग्रासधूम्रं

d. A.B.C. °णे च सलिलाभम् (B. om च)

10a. D. मुखोनचक्रं

b. A.B.C.D. त्रियमद्विगुणं; D. शशि [हीन] संयुक्तम् (A. संयुक्तन्)

c. A.B. एपिक्लेशोयमुश्च (B. त्केशो), (A2 यमुश्च); C. एभिः क्लेशोऽयमुच्चं; D. अभिक्लेशोऽयमुच्चः

d. D. क्रियादिः. B. गो नीयः; D. गो नीचः

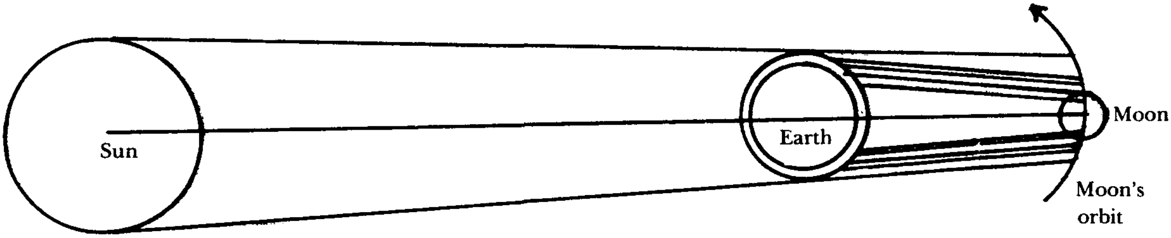


Fig. VI. 6

In its nature this phenomenon is similar to the Sun apparently rising earlier and setting later, and appearing red at both times. As for the distinction between red and brown, it can be seen from the figure that there is great illumination at a greater distance, and, so, when nearer, there is less red, which gives a brown colour as mentioned by the author. The redness may vary by other causes, like the dust or water vapour in the atmosphere, and it goes to the credit of the ancients that distance was distinguished as one cause, affecting the redness.

When the Moon is partially eclipsed, the glare of the illuminated part dims more or less the redness of the eclipsed part, so that it looks almost dark like a rain cloud. Near sunset or sunrise, the red glow from the Moon has again to pass a long distance through the atmosphere, and get filtered out, so that the colour becomes smoky.

Verse 8-A is given only by *Bhaṭṭotpala*, the text manuscripts omitting it. The original of VM must have contained this verse, for it supplies several lacunae. The word *evam* in verse 9 requires a previous verse mentioning colour. Omission of this verse has compelled TS to emend *sarvagrāsiny evam* into *sarvagrāse pītam*. The rule in verse 10, giving when the Moon is at *ucca* and *nīca* has a purpose only with 8-A which requires the information. If TS had verse 8-A before them, they would not have misunderstood 10, and declared that it is something pertaining to astrology. It also instructs us how to find the times of the first and last contacts, and when the middle occurs, which instruction we assumed before, in working the examples. NP rightly include this verse in brackets and give it the number 9, the further verses being numbered from 10.

We have said that verse 10 gives a rule to find when the Moon is far and when it is near. We shall explain how: The rule says that when the result got by the rule is nine *rāśis*, the Moon is at the greatest distance, *i.e.* at *ucca*, and when the result obtained is three *rāśis*, it is nearest, *i.e.* at *nīca*, as we have explained. Therefore if the rule gives about nine *rāśis* for the Moon at *ucca*, i.e. when the Moon is replaced by *ucca*, then it must be correct. We shall show that it is so.

The rule is: Moon $-$ 228 R = *ucca* $-$ 228 R (where R is the Head of Rāhu at *any* full-moon). At the full moon just preceding the Epoch, by II.3, taking the reading *vasumuninava* etc. it can be calculated that according to *Vāsiṣṭha-Pauliśa*, the *ucca* is *rā*. 8-14-21.4. (The *Siddhānta* does not give the *ucca* direct, but we can find it by the relation, Moon $-$ Moon's *kendra* = *ucca*). Every synodic month the *ucca* increases by 3° 17′.3 according to this *Siddhānta*. Therefore after m synodic months, the *ucca* is *rā*. 8-14-21.4 + $m \times$ 3° 17′.3. The corrected Rāhu, R, at the full moon before Epoch is *rā*. 7-26-45.2. It decreases by 1° 33′.88 every synodic month. Therefore, after m synodic months, R = *rā*. 7-26-45.2 $- m \times$ 1° 33′.88

∴ *ucca* $-$ 228 R = *rā*. 8-14-21.4 + $m \times$ 3° 17′.3 $-$ 228 × (*rā*. 7-26-45.2 $- m \times$ 1° 33′.88)
= *rā*. 8-14-21.4 $-$ 228 × *rā*. 7-26-45.2 + m (3° 17′.2 + 228 × 1° 33′.88)
= *rā*. 8-14-21.4 $-$ *rā*. 11-9-45.6 + m (3° 17′.3 + 356° 43′.9)

= *rā.* 9-4-35.8 + $m \times 1'.2$
= practically nine *rāśis*, for a long time after or before Epoch.

Nineteen years before Epoch, this would have been exactly nine *rāśis*. A small difference in Rāhu, (if it is 1′.2 more) would make it nine *rāśis* even at the taken time. It must be noted that one or even two *rāśis* either way will not matter in our context, of redness at one end and brownness at the other, for the difference between redness and brownness itself is slight. Only after two or three thousand synodic months will there be perceptible difference, and the rule cease to hold good.

From the proof of the rule it will be seen that our emendation of *triyamadviguṇam* into *dhīdviyamaguṇam* is necessary. *triyamadviguṇam* had perhaps been wrongly written by some scribe who had the 'saros', (consisting of 223 lunations) in his mind. As antithetical to *kriyādikanyāntago nīcaḥ,* we have emended the meaningless group of letters, *epikleśoyam ucca* into *jūketthageyam uccaḥ.* Neither TS nor NP seem to have understood the significance of this verse. TS observes on it: "A stanza of doubtful import, see the Sanskrit commentary" (Tr., p.45) and the Sanskrit commentary suspects it to be of astrological import (com., p.34). NP gives an incorrect translation and says "The synodic months in an 18 year eclipse cycle is 223, but the role of this number in the present context remains obscure to me" (Pt. II, p.55)

[ग्रहणपरिलेखः]

सप्तदशाष्टत्रिंशत् तद्द्वयलिप्ता (युतोन) सूत्रेण |
शशि (राहु) स्थितिवृत्तान्येक (स्थानानि चाऽऽलिख्य || ११ ||
प्रोक्ता (शशाङ्क) लङ्का-पूर्वाऽप (रायाश्च) पार्श्वयोश्चाऽपि |
आयामिन्यो रेखास्त्रयोदश समान्तराः कार्याः || १२ ||

चन्द्रच्छेदकमेतद् व्याख्यागम्यं समासतोऽभिहितम् |
ग्रासविमर्दस्थितयः संस्थानेनाऽत्र दृश्यन्ते || १३ ||

Diagrammatic representation

11. Draw three concentric circles with radii 17, 38 + 17 (= 55), and 38 − 17 (= 21), minutes of arc. These circles relate to the Moon, the duration and the obscuration, respectively. (Drawing the part of the Moon's orbit forming the path of the Moon), mark the points (of first and last contacts) and also those of inversion and emergence if any).

12. Draw the diameter (making an angle equal to the *Valana* given in verses 7-8), with the ecliptic which, (according to this *Siddhānta*), is east-west with reference to the equator. (This diameter shows the east-west of the place). (As shown in fig. 5c) draw thirteen equally spaced lines parallel to this east-west diameter. (The directions of the points of contact etc. are given by this figure).

13. The graphical representation of the lunar eclipse has here been described briefly, and can be understood properly only by explanation (followed by demonstration). From this, the total duration, the total obscuration, the magnitude, etc. can be found by inspection.

The representation given by the author can do duty for all the figures used by us to explain verses 3, 5, 6 and 7, the centre of the concentric circles being the centre of the Shadow in each. An important difference is that in the previous illustrations, the orbs, of the Moon and the Shadow were shown separately, while here they are replaced by one circle for each of duration (radius = 38′ + 17′) and totality, (radius = 38′ − 17′), the Moon being reduced to a point coinciding with its centre. As the points of contact etc. showing the direction cannot be marked on the point-Moon, another circle is drawn to represent the Moon, with the same centre. As the directions of the points on the two circles are diametrically opposite to the directions of the same points with reference to the Moon, the points can be marked on the Moon-circle by the intersection of the diameter on its opposite half. An examination of fig. 7 will show this, and an example will make everything clear.

Example 3. (Note: This example is intended only as an illustration). The latitude of a place is 20°. The full moon occurs 4 nāḍis after sunset. The Moon at that time is rā. 5-15-0, and the Sun, rā. 11-15-0. The uncorrected Rāhu (Head) at full moon is rā. 5-6-36, from which the latitude is 35′N. The full moon is 11 nāḍis before mid-night. The daily motion of (Moon − Sun) = 780′. Find the times of first contact etc., and verify by a graphical representation.

(i) The corrected Rāhu = *rā*. 5-6-36 − 1° 36′ = *rā*. 5-5-0. Moon ~ Rāhu = *rā*. 5-15-0 − *rā*. 5-5-0 = 10°. This is less than 13°. ∴ there is a lunar eclipse.

(ii) Minutes of duration = $\sqrt{55^2 - \text{lat}^2} = \sqrt{55^2 - 35^2} = 42$, minutes of arc.

Now, 2 × 42 × 60 ÷ 780 = *nā*. 6-28 = Uncorrected duration.

Difference between Moon and uncorrected Rāhu = *rā*. 5-15-0 ~ *rā*. 5-6-36 = 8° 24.

Correction = 8° 24′ × 5 = 42 *vināḍis*.

As Rāhu is less, deducting from uncorrected duration, the correct duration = *nā*. 5-46.

Half this is *nā*. 2-53.

Subtracting from the time of new moon, 4 *nāḍis*, the first contact is at *nā*. 1-7 after sunset.

Adding, the last contact is at *nā*. 6-53.

(iii) Moon ~ cor. Rāhu = 10°. As this is greater than 5°, there is no total phase.

(iv) The first contact is *nā*. 15-0 − *nā*. 1-7 = *nā*. 13-53 before midnight, *i.e.* the Moon is 83° east of the meridian,

11a. A.B.दशाष्टा
B1.2.त्रिंशतद्वय; B3.त्रिंशद्वय
b. A.मतेन सूत्रेण; B.C.D.मितेन सूत्रेण
c. A.B.शशिना बहुस्थिति (A2.नां)
d. A.नि एक छेना निषालेख्य; B.नि एकष्ठत्रो निवासलेख्य;
D. न्येकस्थानि वा संलेख्य

12a. A.प्रोक्तायां सकलङ्का; B.प्रोक्ता यो सवूलांका (B2.बू)
D.प्रोक्ताया [मं] शकलका [त्]
b. A.B.D.पूर्वापरयोश्च (A om र); C.पूर्वापरायाश्च
d. A.समात्तारा:; B.समां तारा:

13a. A.छेदक; B.ष्ठेदक; C.D.छेद्यक
d. B1.मंस्थानेनात्र (B2.3.सं॰)

The Moon's circumference = 17′ × 44/7 = 107′.

The bending of the direction due to latitude = (107′/4) × 20 × 83 ÷ 8100
= 5½ minutes of arc.

As Moon is east of the meridian, the equatorial east point is bent 5½′ north of the east point of the place, i.e. the east point of the place is situated south by 5½ minutes-length.

At the time of last contact, the Moon is 49° east of the meridian. The bending of the point of last contact at the western limb of the Moon =(107/4) × 20 × 49/8100 = 3.2′, southward, as the Moon is east of the meridian, i.e. the west point of the place is 3½ minutes-length north of the equatorial west point.

(v) We shall show all these graphically in Fig. 7. The latitude to be used in the figure is the corrected latitude = 10° × 380′ ÷ 90 = 42′N.

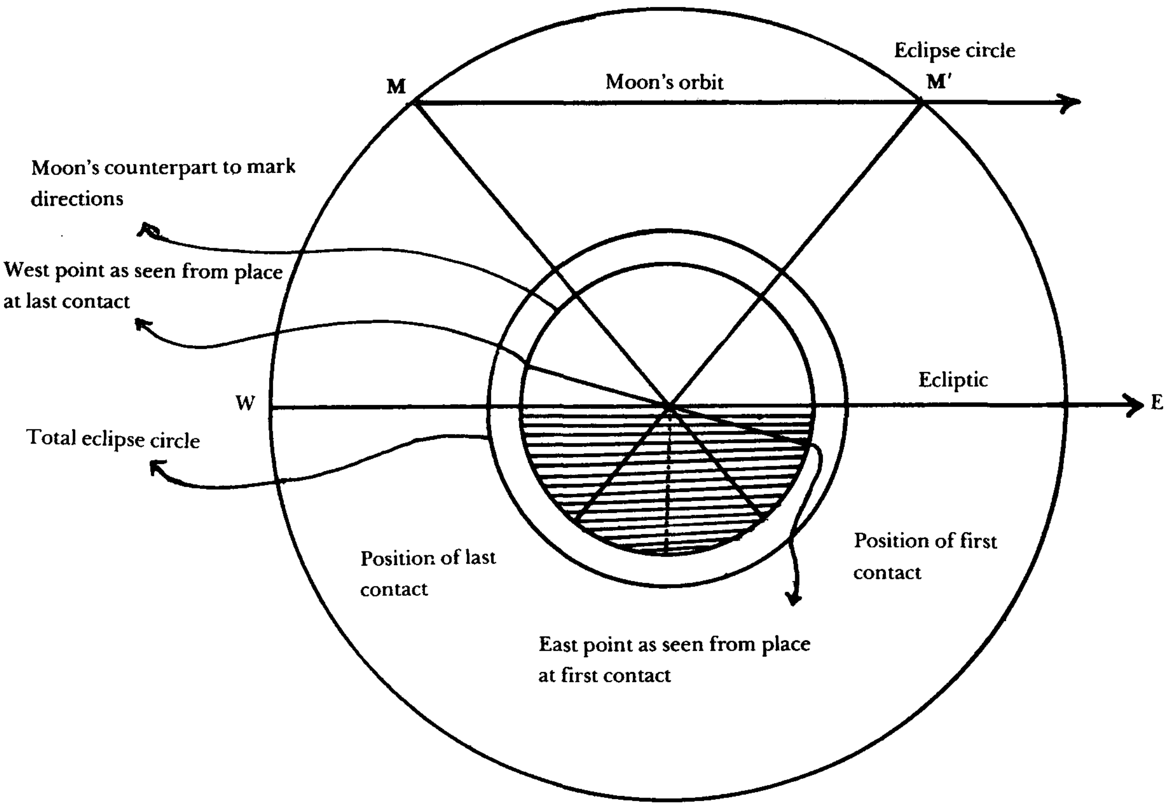


Fig. VI. 7

M, M′, are the points of first and last contacts. MM′ = duration in minutes of arc. MM′ = 3″.6 by measurement, = 3.6 × 20′ = 72′.

From this, the time of duration = 72 × 60 ÷ 780 = *nā*. 5-32.

See how close this is to the time calculated, viz. *nā*. 5-46.

The Moon's orbit does not touch the circle of totality. Therefore there is no total obscuration, as already found by calculation.

The arc in the figure from the east point of place to the first point of contact gives the direction of the point at the beginning, and the arc from the west-point of place to the point of last contact gives the direction at the end.

We have amended *matena* into *yutona*, *nabahu* into *Rāhu*, *ekachanoni* into *ekasthānāni*, *yāṁasabū* into *śasāṅka* and *pūrvāparayośca* into *pūrvāparāyāśca* as necessitated by the context and proximity of the lettering.

[रविचन्द्रग्रहणयोर्भेदः]

स्वे भूच्छायामिन्दुः स्पृशत्यतः स्पृश्यते न पश्चार्द्धे |
भानुग्रहेऽर्कमिन्दुः प्राक् प्रग्रहणं रवेर्नाऽतः || १४ ||

Lunar and solar eclipses – Differences

14. In the lunar eclipse, the Moon, (moving eastward), contacts the earth's shadow. Therefore the 'first contact' (occurs at the eastern limb of the Moon, and so) does not occur at the Moon's western limb. In the solar eclipse, the Moon meets the Sun, and therefore, (the Sun being contacted as its western limb), the first contact does not occur at the eastern limb of the Sun.

The Moon's motion being more than thirteen times that of the Sun or the Shadow, (whose motion is the same as that of the Sun), it moves eastwards relative to the Sun or Shadow and contacts them at their western limb, and its own eastern part. As the lunar and solar eclipses are with reference to the Moon and the Sun, respectively, the first contacts are at the eastern and western limbs, respectively. It need not be mentioned that the last contacts are, respectively, on the western and eastern limbs.

14. Quoted Utpala on *BS*. 5.12
12a. U. स्वं. B1.2. भूयष्ठायां; B3. भूष्ठायां. A.B. ०मिन्दु
b. AB.3. स्पृशतः स्पृ०; B1.2. स्पृश्यतः स्पृ०
C. स्पृशति तथा स्पृशति दृश्यते पश्चात् |
A. पश्चार्द्धे; B.D. पश्चार्धः
c. A.B1. भागनुग्रहे. A.B.C.D.U. मिन्दोः
d. A. र्खे

[इति पञ्चसिद्धान्तिकायां वराहमिहिरविरचितायां
चन्द्रग्रहणं नाम षष्ठोऽध्यायः |][1]

Thus ends Chapter Six entitled '(Vāsiṣṭha-) Pauliśa Siddhānta: Lunar Eclipse' in the Pañcasiddhāntikā composed by Varāhamihira

1. A.B.D. चन्द्रग्रहणं षठोऽध्यायः C. इति चन्द्रग्रहणं नाम षष्ठोऽध्यायः

Chapter Seven

(PAULIŚA-SIDDHĀNTA) – SOLAR ECLIPSE

७. सप्तमोऽध्यायः
पौलिशसिद्धान्तः — रविग्रहणम्

Introductory

This chapter deals mainly with the solar eclipse according to the *Pauliśa*. But the last two verses giving the computation of the solar eclipse gives the lunar eclipse also. It is from this that we have to conclude that the lunar eclipse of Chap VI is that of the *Vāsiṣtha.* The method of the *Pauliśa* for correcting the Moon's latitude for parallax is peculiar. The correction is done on Rāhu, and thence carried to the latitude. Also, this is the earliest *siddhānta* to deal with the solar eclipse, and thus, with its peculiar method, historically important.

[लम्बनम्]

दिनमध्यमसंप्रा(प्या) यावत्यो नाडिका व्यतीता वा |
ताभ्यः षड्गुणिताभ्यो ज्यात्रिंशांशस्तिथे(नामः) || १ ||

Parallax of longitude

1. Find the interval between mid-day and the time of new moon, in *nāḍis.* Multiply this by 6. Degrees are got. Find its sine. Divide it by 30. The result is the parallax in *nāḍis* to be deducted from the time of new moon if new moon is before mid-day, and to be added to the time of new moon, if after mid-day. The new moon corrected for parallax in longitude is obtained.

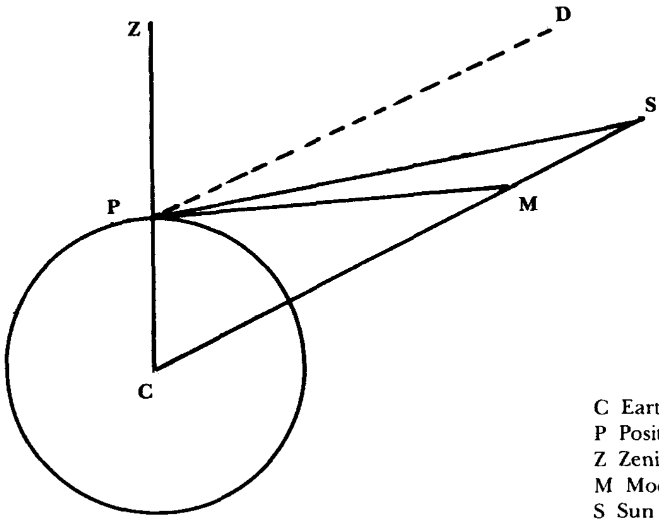
Thus: i. *nāḍis* of parallax = sine (interval in *nāḍis* between mid-day and new moon × 6) ÷ 30.

ii. Parallax corrected new moon = new moon ∓ (i), *minus* for forenoon, and *plus* for afternoon.

The rationale of parallax correction is as follows: A lunar or solar eclipse occurs when the Moon gets so close to the earth's shadow or the Sun, that it enters the Shadow so as to be darkened by it, or hides the Sun from the observer's view. Now, the Moon being darkened by the Shadow is practically independent of the position of the observer on the earth. But the Moon hiding the Sun depends upon the observer's position, owing to parallax. So parallax correction has to be done in the solar eclipse. The critical angular distance is the sum of the semi-diameters. The angular distance between the Sun and the Moon is calculated from the longitudes of both and the latitude of

1a. A.B.C.D. संप्राप्ता
b. B1.2. यावन्त्यो A. व्यतीता वत; B. व्यतीता वत्त ।
c. B. गुणितान्यो
d. A.B. ज्यास्त्रिंशांशः A.B. तीथिर्नाम; C. तिथेर्नाम

the Moon. These being given with reference to the centre of the earth, the angular distance calculated is as seen by an observer at the centre of the earth. But we want the distance as seen by an observer on the surface of the earth, and a correction has got to be made for this. This is correction for parallax or simply parallax. See Fig. 1-a.



C Earth's centre
P Position of observer
Z Zenith
M Moon
S Sun

Fig. VII. 1-a.

(*Note*: The figure is only diagrammatic and does not represent actual distances).

PD = a line drawn parallel to CM.

The observer at C sees the Moon along CM, and for him the Moon's zenith distance (z.d.) is ZCM (= ZPD). But the observer at P sees the Moon along PM, and its z.d. for him is ZPM. This is equal to ZPD + DPM = ZCM + PMC, and PMC is the parallax correction to ZCM. It can be seen that the parallax correction for the Sun is PSC, and less than that for the Moon. It is actually about 2/27 of the parallax of the Moon, according to the Hindu *Siddhāntas*, its distance being about 27/2 times that of the Moon, according to them. (It must be noted that actually the Sun's distance is about 390 times the Moon's, and accordingly the Sun's parallax is about 9″, and practically negligible).

The amount of parallax, PMC can be calculated trigonometrically thus:
Sin PMC/PC = sin CPM/CM
= sin (PCM + PMC)/CM
= sin PCM/CM (∵ PMC is small).
Sin PMC = sin CPM × PC/CM.
Arc PMC × 120/57.3 = sin CPM × PC/CM (∵ PMC is small).

$$\text{Parallax of Moon in minutes} = \frac{\sin \text{z.d.} \times (PC/CM) \times 60 \times 57.3}{120}$$

= sin z.d. × 28.65 × Earth's radius/Moon's distance.

Similarly, the Sun's parallax in minutes = sin z.d. × 28.65 × Earth's distance ÷ Sun's distance.

At a solar eclipse, z.d. is practically equal for the Moon and the Sun, and in measuring the angular distance between the Sun and the Moon relative parallax can be applied to the Moon, the Sun being supposed unaffected. We can write:

Relative parallax = Moon's parallax − Sun's parallax

= sin z.d. × 28.65 × earth's radius × (1/Moon's dis. − 1/Sun's dis.)

When the Sun or Moon is at the horizon, sin z.d. is 120, and the relative parallax, (hereafter we shall call it merely parallax), called horizontal parallax, is a maximum, and this *Siddhānta* takes it as equal to 49′.

∴ Parallax = 49′ sin z.d./120.

Also, we can see from the fig. 1a that the Moon is depressed, away from the zenith by parallax, along the vertical circle, ZM, increasing the z.d. and that is why it is called *lambanam*, i.e. 'depression', in Sanskrit.

This general parallax has to be resolved into two parts, correction to longitude, (p. long.) and correction to latitude (p. lat.). This is shown in fig. 1b.

Z Zenith
N Nonagesimal (Lagna − 90°)
O Orient ecliptic point (Lagna)
A First point of Aries
MAQ = ω

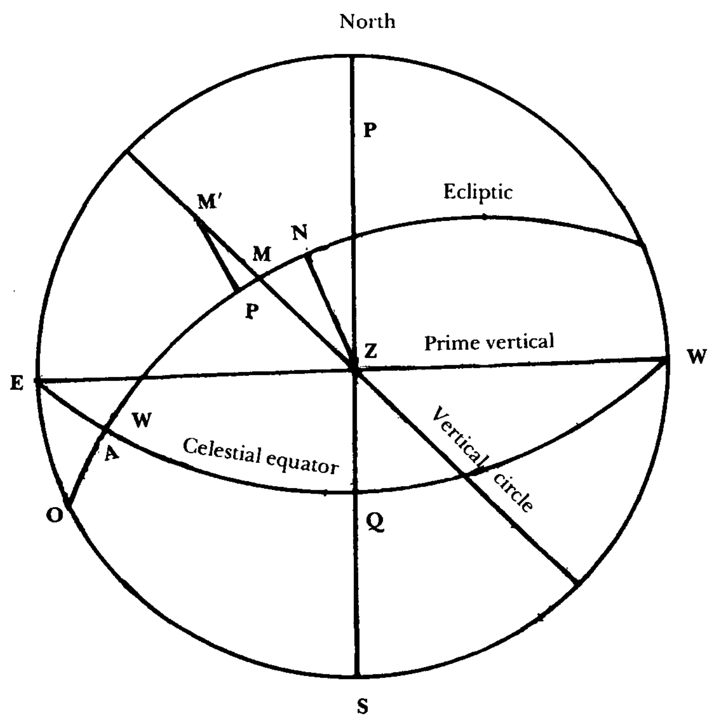


Fig. VII. 1-b.

ZM = z.d., and MM′ is the general parallax.
PM′ is the parallax in latitude, and MP, that in longitude ZQ.
= latitude of the place, and ZN is the zenith distance of the nonagesimal (z.d.N.).
We shall find an expression for PM′, the p.lat.
p.lat = PM′ = MM′ × sin M′ MP/120
= 49′ sin ZM × sin ZM N/120^2
= 49′ sin ZN/120
= 49′ sin zdN/120, (from rt △ MNZ).
Similarly for p.long, i.e. MP,
p.long = MP = MM′ cos M′ MP/120 = 49′ sin ZM. cos ZMN/120^2
= 49′ cos ZN × sin MN/120^2 (from rt △ MNZ)
= 49′ cos z.d.N × cos OM/120^2, OM being (*lagnam* − Moon).

Clearly, this is positive when the Moon is east of the nonagesimal, and negative when west.

It is p.long. that we are concerned with in this verse, and it must be given in terms of the hour-angle (h, or *natāṃśa*)

cos z.d.N × cos OM = (i) cos w. cos ϕ. sin h. sec δ [δ being the Moon's declination] + (ii) [sin w × cos Moon's longitude × {cos ϕ × tan δ × sin (*nāḍis* after sunrise or before sunset × 6°)/120^2} − sin ϕ/120].

The *Siddhānta* omits (ii) which is small in comparison with (i), sin ϕ/120 being small in India. For the same reason, and as w and δ cannot exceed 24°, it takes cos w. cos ϕ. sec δ as 120.

∴ p.long = 49′ sin h/120.

As said before, this is positive, i.e. it increases the Moon's longitude when h is east, and negative, i.e. it decreases, when h is west. Therefore the corrected time of new moon is earlier and subtractive in the forenoon, and later and additive in the afternoon.

Now, 49′ of p-long, converted into time, using the mean relative daily motion of the Sun and the Moon, (731′.5), = 49′ × 60/731′.5 = 4 *nāḍis* nearly.

∴ *nāḍis* of parallax = 4 × sin h/120 = sin h/30, as given by the text. If (ii) is not neglected, the Moon being east or west of the nonagesimal will be the criterion for the subtraction and addition of the *nāḍikās*.

[नतिः]

पञ्चघ्नात् '(त्रि)घना'ऽऽप्तादक्षान्मुखपु(च्छ)योर्धनर्णे तत् ।
(सशशि)चरणा(पमगुणा) धनर्णनाड्यो '[धृति]'विभक्ता ॥ २ ॥
उद्गयने पूर्वार्धे धनमृणं दक्षिणे प्राच्याम् ।
पश्चाद्धनं तु याम्ये (दि)गुदगृणं वामतः पुच्छे ॥ ३ ॥
दिनयातशेषनाड्यश्चन्द्रा(पम)संगुणास्त्वशीतिहृताः ।
(मे)षतुलादि ऋणधनं विपरीतं वामतः पुच्छे ॥ ४ ॥

Parallax in latitude

2. Multiply the degrees of latitude by 5 and divide by 27. Add or subtract the resulting degrees, respectively, to Rāhu's head or from Rāhu's tail, where the Moon is situated. (i)

3. Add three *rāśis* to the Moon, and find its declination in degrees. This multiplied by the *nāḍis* of parallax (given by verse 1) and divided by 18, are to be added to the Head if it is forenoon and *Uttarāyaṇa* (i.e. the Sun is in its northward course), or afternoon and *Dakṣiṇāyana*. The degrees are to be subtracted from the Head if it is forenoon and *Dakṣiṇāyana* or afternoon and *Uttarāyaṇa*. For the Tail, the addition and subtraction should be interchanged. (ii)

4. Take *nāḍis* from sunrise to new moon if forenoon, the *nāḍis* from new moon to sunset if afternoon. Multiply these by the degrees of the Moon's declination and divide by 80. The resulting degrees are to be added to the Head if the Moon's longitude is between 6 and 12 *rāśis*, and subtracted if between 0 and 6 *rāśis*. For the Tail, interchange the addition and subtraction. (iii)

The corrections are:

i. $\emptyset^\circ \times 5 \div 27$

ii. 'Degrees' × the *nāḍis* of verse 1 ÷ 18, where 'Degrees' are to be got from sin 'degrees' = sin w sin (Moon + 90°)/120

iii. Degrees of Moon's declination × the time in *nāḍis* from sunrise to (parallax corrected) new moon, or to sunset from parallax corrected new moon ÷ 80. The addition or subtraction is as instructed in the translation above.

These rules follow from the formula derived already for parallax correction in latitude:
p-lat = 49′ sin z.d.N/120.

$49'$ sin z.d. N/120 = sin w. cos $\emptyset$ sin (AQ)/120^3 − cos w. sin $\emptyset$/120^2, (from the two rt. △ s. Z NA and Z QA)

= (i) − 49′ cos w, sin $\emptyset/120^2$ + (ii) − 49′ sin ω cos $\emptyset$ sin (Moon + 90°) × sin h. sec $\delta/120^3$ + (iii) + 49′ cos ω.cos $\emptyset$ tan δ.cos h/120^3, (h being the hour angle of the Moon at parallax-corrected new moon).

2a. A.B1.पञ्चघ्नस्त्रि°. D.यमाप्ता

b. B1.दक्षन्; D.[क्षेपो]क्षे मुख. A.पुछ्योः; B1.2.पृष्ठयोः

A.B.धनर्णे तन्न |; D.धनर्णः

c. A.B.C.राशिचरणा°; D.तद्राशिचरणा°;

A.B.C.D.°यनगुणं

d. A.B.C.धनमृणनाड्यो (B1.3.°ताड्यो).

A.B.C.D.दिक°

B.विभक्ता

3a. B.धनं मृणं

b. A.दिणे; B.दक्षिणं

c. A.यश्चाधनं

d. A.om दिगु; B1.दगुगृणं; B3.दृगुदगृणं; C.D.om दिग्

A.पुछे; B.पृष्ठे

4a. B.शेषं

b. A.C.D.चन्द्रायन; B.चन्द्रानयन A.त्रशीति;

B.श्चाशीति

B1.ऋताः; B2.3.क्षताः

c. A.B.शेष. D.तृलाधृणं घनं

d. B.विपरितं. A.B.पुछे

To secure correction 49′ in latitude, a correction = 90° × 49/380 = 11°.6, must be applied to Moon ~ Rāhu which can be done by applying it to Rāhu, as the *Siddhānta* does. The purpose of this replacement is to extend the method of computing the lunar eclipse using Moon ~ Rāhu to the solar eclipse also. So 49′ has to be replaced by 11°.6 in the rules, (i), (ii) and (iii).

We shall take the rules one by one and derive the *Siddhañta* rules.

(i) $= -11°.6 \cos \omega \sin \phi / 120^2$

$= -11°.6 \times 109.6 \times$ (degrees of latitude $\times$ 120/57.3)/120^2, (∵ when latitude is not much, its sine ∝ degrees)
$= -5 \times$ degrees of latitude ÷ 27, as given.

As the *Siddhānta* has only the north latitudes in view, this part of p.lat is always negative. Therefore Moon's north-latitude must become less, and south latitude more, by the correction. This can be done by increasing Rāhu-Head, i.e. by adding the correction to the Head, and by decreasing Rāhu's Tail, i.e. by subtracting from the Tail, as instructed.

(ii) $= -11°.6 \sin \omega \cos. \phi \sin (\text{Moon} + 90°) \sin h. \sec \delta / 120^3 = -11°.6 \sin \omega . \sin (\text{Moon} + 90°)$ × *nāḍis* of correction to new moon ÷ (cos ω × 120 × 4), (∵ sin h = 120^2 × *nāḍis* of correction × cos δ ÷ (cos ω × cos ϕ × 4), in verse 1).
= − 11°.6 × sin declination of point (= Moon + 3 *rāśis*) × *nāḍis* of correction ÷ (109.6 × 4)
= − 11°.6 × {Degrees of declination of point (= Moon + 3 *rāśis*) × 120/57.3} × *nāḍis* of correction ÷ (109.6 × 4)
= − 'Degrees' of declination of point (= Moon + 3 *rāḍis*) × *nāḍis* of correction to new moon ÷ 18.

The 'Degrees' are north, *i.e.* positive for Moon's *Uttarāyaṇa*, and negative for *Dakṣiṇāyana*. The *nāḍis* stand for positive p-long in the forenoon, and negative p-long in the afternoon as already shown. Thus, for *Uttarāyaṇa* and forenoon, the p-lat is negative, and so the result of (ii) is to be added to Head, and subtracted from Tail. Clearly, it is the same for *Dakṣiṇāyana* and afternoon, as then also p-lat is negative. If *Uttarāyaṇa* and afternoon, or *Dakṣiṇāyana* and forenoon, p-lat. becomes positive, and so the correction is subtractive to Head, and additive to Tail, as instructed.

(iii) $= +11°.6 \cos \omega . \cos \phi . \tan \delta . \cos h / 120^3$.

$= +11°.6 \times 109.6 \times \cos \phi \times \sin \delta \times \cos h \div (\cos \delta \times 120^3)$
= + 11°.6 × 109.6 × degrees of Moon's declination × cos h ÷ (120 × 57.3), (∵ sin δ = degrees of declination × 120 ÷ 57.3, nearly, and taking cos ϕ/cos δ as equal to unity, δ being not great, and ϕ being not great in India) = + 11°.6 × 109.6 × δ × *nāḍis* after sunrise or before sunset ÷ (120 × 57.3 × 15), ∵ the *Siddhānta*, takes cos h as equal to *nāḍis* after sunrise or before sunset ÷ 15, being satisfied with approximate values, i.e. ϕ not being great, the time from sunrise or sunset to noon is taken as 15 *nāḍis* always. Secondly, the angle is taken as ∝ to sine, as often done before.

∴ cos h = sin (90° − h) = (90° − h)/90°
= (15 *nāḍis* − *nāḍis* to meridian)/15 = *nāḍis* after sunrise or before sunset ÷ 15
= + δ × *nāḍis* after sunrise or before sunset ÷ 80)
δ is north, i.e. positive for Moon, 0 to 6 *rāśis*, and negative for Moon, 6 *rāśis* to 12 *rāśis*. The original of the *nāḍis* cos h, is positive both forenoon and afternoon.

∴ p.lat is positive for Moon between 0 to 6 *rāśis*, and so the result is deducted from Head and

added to Tail if Moon is between 0 and 6 *rāśis*. For Moon between 6 *rāśis* and 12 *rāśis* δ is negative and p.lat. is negative, and therefore the result is to be added to Head and subtracted from Tail.

Thus, by making the three corrections to Rāhu, p.lat. is secured, though approximately.

TS have not translated or explained these three verses, not having understood the exact form of the rules or their derivation. They merely surmise that it is some work done on Rāhu to correct the latitude for parallax. NP too have not understood these verses correctly for they say in the notes to verse 2. "This verse is corrupt" etc., in the notes to verse 3, "The text as it stands seems to have confused the different cases" and in the notes to verse 4, "The text *seems* to instruct us" etc. (pt. II, p.57).

In accordance with the correct form of the rules, we have in verse 2, emended *dvika* into *dhṛti*, *rāśicaraṇāyana* into *sarāśicaraṇāpama* and *candrāyana* into *candrāpama*.

[ग्रहणकर्म]

राहोः स'षट्कृति'कलां हि(त्वांशं) त(च्छ)शाङ्कविवरांशैः |
ग्रहणं त्रयोदशान्तः शशिनो भानोस्तथाष्टान्तः || ५ ||

तद्वर्ग(मपास्ये)न्दो'(र्न)वर्तुरूपात्' ('श्रुतिरसा'च्च) |
तन्मूलं पादोनं स्थितिकालश्चन्द्रभान्वोश्च || ६ ||

Eclipse computation

5. Deduct 1° 36′ from Rāhu and find Moon ~ Rāhu, in the case of the lunar eclipse. Deduct 1° 36′ from Rāhu corrected (by verses 2-4) and find Moon ~ Rāhu, in the case of the solar eclipse. If the difference is less than 13° there is a lunar eclipse. If the difference is less than 8°, there is a solar eclipse, (otherwise not).

6. For the lunar eclipse, deduct the square of the difference from 169, find its square root and take three fourths of it. This is the total duration in *nāḍis*. For the solar eclipse, deduct the square of the difference from 64, find its square root, and take three fourths of it. This is the total duration in *nāḍis*.

Thus, *nāḍis* of total duration = $\frac{3}{4}\sqrt{169 - (\text{Moon} \sim \text{Rāhu})^2}$, or $\frac{3}{4}\sqrt{64 - (\text{Moon} \sim \text{Rāhu})^2}$, respectively. Half this subtracted or added to the full moon, or parallax corrected new moon, gives the times of first and last contacts.

5a. A.किलां; B.कला
b. A1.हित्वा सं; A2.हिचा सं; B.हिच स. A.B1.2.तछ
d. B.तथाष्ठीतः
6a. AB.1.2 समासेन्दो
b. A.B.न वर्तु (B.चर्तु) रूपान्नचेष्टतरसाश्रु (B.सश्रुत) ।
C.D.रूपाद्रवेः श्रुति (D.कृत) रसाच्च
c. A.पादोन
d. A.B.भानोश्च

The formulae here are similar to that of VI. 5 as reduced by us, giving the total duration in the lunar eclipse, according to *Vāsiṣṭha*. Therefore, the explanation is similar. As in the Vasiṣṭha, in the *Pauliśa* too, the limit of the lunar eclipse is seen to be 13°, giving 55′ latitude. Therefore, in the *Pauliśa* too, the sine of the semi-diameters of the Shadow and the Moon is 55′, wherefrom their respective semi-diameters may be taken as the same, i.e. 38′ and 17′. The limit of the solar eclipse is seen to be 8°, at which the latitude is 8 × 55′/13 = 33′.8. Therefore the sum of the semi-diameters of the Sun and the Moon is 33′.8, from which the semi-diameter of the Sun is found to be 16′.8. If actually the Moon's semi-diameter is a little more or less in the *Pauliśa*, to that extent that of the Sun must be less or more. But we have no means of knowing it exactly, since the original *Pauliśa* is not extant, the *Pauliśa* quoted by *Bhaṭṭotpala* in the *Bṛhat Saṁhitā* being different, as already mentioned.

From the formulae, the minutes of arc pertaining to duration is, $55' \times 2\sqrt{169 - (\text{Moon} \sim \text{Rāhu})^2}/13$ in the case of the lunar eclipse. To be correct, the time must be found from this by dividing by the true relative motion, which is not done here. If the mean relative motion is used, we get:

$\{2 \times 55\sqrt{169 - 0}/13\} \times 60 \div 731.5 = 9$, being the *nāḍis* for the maximum. But, by the formula, the maximum is, $3\sqrt{169 - 0}/4 = 9\frac{3}{4}$ *nāḍis*. But this is nearer the correct value. For the solar eclipse the maximum by the formula is, $3\sqrt{64 - 0}/4 = 6$ *nāḍis*. But actually, in the solar eclipse the maximum differs according to the time of new moon, being about 5 *nāḍis* at sunrise or sunset, and about 10 *nāḍis* near moon.

TS, in their explanation here, take the maximum lat. to be 270′, instead of their taking 240′ for the *Vāsiṣṭha*. But, by this, the respective sums of semi-diameters must be got as 61′ and 38′. But they give 58′ and 35′, which is quite wrong. They seem to have taken these wrong values deliberately, with a view to deriving the formulae using the mean relative motion. NP too have failed to get the correct meanings and so close their notes on verse 7 with the statement "We cannot explain the origin of this discrepancy" (pt. II, p.59), the apparent discrepancy being in the formula for total duration of the eclipse as calculated by them. We shall illustrate the whole thing with two examples.

Example (a). In chap. VI, example 3, the Moon at full-moon was given as rā. 5-15-0, and Rāhu at that time as rā. 5-6-36. Compute the lunar eclipse:-

The Rāhu corrected for eclipse = *rā*. 5-6-36 − 1° 36′ = *rā*. 5-5-0
Moon ~ Rāhu = rā. 5-15-0 − rā. 5-5-0 = 10°
Total duration = $3\sqrt{169 - 10^2}/4 = 3 \times 8.307/4$ = *nā*. 6-14.
(Compare this with the *nāḍis* got by *Vāsiṣṭha*, *nā*. 5-46).

Example (b). The latitude of Pudukkottai in S.India is 10° 24′ N. On a certain day, there, sunrise is nā. 28-40, after sunset, midday is after nā 44-20, and new moon is after nā. 49-20 The Sun = Moon = rā. 2-0-0, at new moon and Rāhu (Tail) is rā. 2-1-0, Compute the solar eclipse, if any, at Puḍukkottai.

First, Parallax-corrected new moon:-
Time of new moon ~ time of midday = *nā*. 49-20 − *nā*. 44-20
= 5 *nāḍikās*, west.
= 5 × 6 = 30°, degrees from meridian west.
Correction for new moon = sin 30°/30 = 60/30 = 2, *nāḍikās*.
Degrees being west, adding to new moon, the parallax corrected new moon = *nā*. 49-20 + *nā*. 2-0
= *nā*. 51-20.

Next, correction to Rāhu:

(i) 5 × 0/27 = 5 × 10.4/27 = 1° 56′. As the Moon is near the Tail, this is to be subtracted.

∴ Tail − 1° 56′ = *rā* 2-1-0 − 1° 56′ = *rā*. 1-29-4.

(ii) Correction to new moon = 2 *nāḍis*.
(Moon + 3 *rāśis*) = 5 *rāśis*.
The declination of this point is 11° 44′.
The correction = 2 × 11° 44′/18 = 1° 18′.
As new moon is afternoon, *Uttarāyaṇa*, and Tail, this is additive. Adding to corrected Tail we get, *rā*. 1-29-4 + 1° 18′ = *rā*. 2-0-22.

(iii) The *nāḍis* of corrected new moon before sunset = Sunset ~ cor. new moon = 60 *nāḍis* − *nā*. 51-20 = *nā*. 8-40.

The Moon's declination, from its longitude, is 20° 36′.

The correction, = 8 2/3 × 20° 36′ ÷ 80 = 2° 14′.

As the Moon is between 0 and 6 *rāśis*, and it is Tail, this is additive.

Adding to corrected Tail, we get, *rā*. 2-0-22 + 2° 14′ = *rā*. 2-2-36.

Subtracting 1° 36′ from the corrected Tail, we have *rā*. 2-2-36 − 1° 36′ = *rā*. 2-1-0, as corrected Rāhu to be used in the formula:

Moon ~ Rāhu = *rā*. 2-1-0 − *rā*. 2-0-0 = 1°
As this is less than 8°, there is a solar eclipse.
Duration = $3 \times \sqrt{61 - 1^2/4}$ = 5-57 *nāḍis*.
Half this is *nā*. 2-59.
Subtracting and adding this to the corrected new moon, we have:
Time of first contact = *nā*. 51-20 − *nā*. 2-59 = *nā*. 48-21
Time of last contact = *nā*. 51-20 + *nā*. 2-59 = *nā*. 54-19

We have already said that the results will be very rough.

[इति पञ्चसिद्धान्तिकायां वराहमिहिरविरचितायां
रविग्रहणं नाम सप्तमोऽध्यायः ||] [1]

1. Col. A.B.C.D. इति (A.D. om इति) पौलिशसिद्धान्ते रविग्रहणं नाम (A.B.D. om नाम) सप्तमोऽध्यायः

Thus ends Chapter Seven entitled 'Pauliśa-Siddhānta – Solar Eclipse' in the Pañcasiddhāntikā composed by Varāhamihira

Chapter Eight

ROMAKA-SIDDHĀNTA — SOLAR ECLIPSE

८. अष्टमोऽध्यायः
रोमकसिद्धान्तः — रविग्रहणम्

Introductory

In this chapter the Sun, Moon and Rāhu according to the *Romaka Siddhānta* are given, as also the solar eclipse, dependent on these. But the lunar eclipse is not dealt with. We have already mentioned that this *Romaka* is different from the *Romaka* extant now.

[स्फुटरविः]

रोमकसूर्यो द्युगुणात् 'खतिथि'(घ्नाः) 'पञ्चकर्तु'परिहीणात् |
'सप्ताष्टकसप्तकृतेन्द्रियो'द्धृतान्मध्यमः [क्रमशः] || १ ||
रविशशिनोः स्फुटकरणं स्वके(न्द्र) भवनार्धसंमितैः खण्डैः |
(व्यु) त्क्रमशश्च पुनस्तैर्मिथुनद (लं) शोध्यतेऽर्कस्य || २ ||
'तिथि-मनु-दश-कृत'सहिता 'रस-मनु'हीना(भिश्च) 'विंशति'र्हीना
'धृति-विषयो'ना 'द्वि-दशा-ष्टि-धृति'षु वृद्धिः कलाविकलाः || ३ ||

True Sun

1. According to the *Romaka*, the mean Sun in revolutions etc. is obtained by multiplying the Days from Epoch by 150, deducting 65 from the product, and dividing by 54,787.

2. Both the Sun and the Moon are to be made true by intervals of the equation of the centre for half-signs of the respective mean anomalies given for the first three signs. For the next three signs they are to be taken in the reverse order. This is repeated for the next six signs. In the case of the Sun, the anomaly is got by deducting *nā*. 2-15-0 from the mean Sun.

3. The minutes of intervals for the Sun, are 20 + 15, 20 + 14, 20 + 10, 20 + 4, 20 − 6 and 20 − 14, from which seconds 18 and 5, are to be subtracted, and 2, 10, 16 and 18 are to be added, in the given order.

Thus,

(i) Mean Sun = (Days from epoch × 150 − 65) ÷ 54,787.

(ii) The mean anomaly of Sun = Mean Sun − *rāśi* 2-15-0.

(iii) The intervals of equation of the centre are 34′ 42″, 33′ 55″, 30′ 2″, 24′ 10″, 14′ 16″ and 6′ 18″. These are subtractive in the given order in the first quadrant of anomaly, additive in the reverse order in the second quadrant, additive in the given order in the third quadrant, and subtractive in the reverse order in the fourth quadrant.

(iv) True Sun = (i) + (iii)

Example 1. Compute the true Sun, for the moment, 59 days from Epoch.

(i) Mean Sun = (59 × 150 − 65) ÷ 54,787 = *rāśi* 1-27-44.

(ii) Mean anomaly = *rāśi* 1-27-44 − *rāśi* 2-15-0 = *rāśi* 11-12-44.

(iii) The equation of the centre = −34′ 42″ −33′ 55″ −30′ 2″ −24′ 10″ −14′ 16″ −6′ 18″ +6′ 18″ +14′ 16″ +24′ 10″ +30′ 2″+33′ 55″ +34′ 42″ +34′ 42″ +33′ 55″ +30′ 2″ +24′ 10″ +14′ 16″ +6′ 18″ −6′ 18″ −14′ 16″ −24′ 10″ −30′ 2″ −33′ 55″ × 12° 44′ ÷ 15° (= −28′ 47″) = +39′ 50″.

(An examination of work (iii) will suggest how to get the total easily).

(iv) Adding to the mean Sun,

True Sun = *rāśi* 1-27-44 +40′ = *rāśi* 1-28-24.

It must be noted that this is at mean sunset at Yavanapura.

The rule for the mean Sun can be derived from the constants given or derivable from I.15. There it was shown in the Notes that in the Romaka yuga consisting 2850 solar years, there are 10,40,953 civil days. Thus, as the solar year is the period of revolution of the Sun, the number of revolutions, say in *x* days, is = x × 2850 ÷ 10,40,953 = x × 150 ÷ 54,787, as given. As for the deductive constant, 65, we infer that according to the *Romaka*, 65/150 days after epoch the mean Sun was a full revolution, but we cannot verify this, the original *Romaka* being lost. But it must agree with the relevant constant in I.10, and we have shown in the Notes there that it indeed does. We have also shown there that this mean Sun is tropical, and not sidereal. This is peculiar to the *Romaka*.

The Sun's apogee given as *rā*. 2-15-0 is what the *Romaka* must have found by observation and computation, and we have to take it as it is. Actually, the apogee was at *rā*. 2-17-19 at epoch.

As for the intervals of the equation of the centre, the *Siddhānta* is right in giving them in accordance with the anomaly. But the values are slightly different from what they will be if the correct terms, a sin θ + b sin 2 θ, has been used. Therefore, either the *Romaka* gives only empirical values obtained from observation, like the *Pauliśa*, or the *Romaka* like the *Sūrya Siddhānta* etc., apply an equation on the epicycle itself. Any deviation from this may be due to scribal errors. Taking the sum

1. Quoted by Utpala on *BS* 2.p.40

1a. A1.सूया; A2.सूर्यो
b. A.B1.C.D.तिथिघ्नात्; B2.3.घ्नां च.
A.B.परीहीणान्न
c. B.॰ष्टकमाप्तत ते
d. A.B.॰द्ध (B.धृ) तान्मध्यमाः || U.मध्यमः सूर्यः
2a. A.स्फुटकरणं; B.स्फुरठकरणं
b. A.B.स्वकेन्दु. B.भवनाद्धम् - सं॰
c. A.B.C.D.तत्क्रम
d. A.B.दल; C.दलात्. B.॰तेकस्य
3b. A.B.हीना भाविंशतिर्हीना (B.विंशतिहीना)
C.॰म्नुभिर्विंशतिहीनाः. D.॰म्नु[वि]हीना च विंशतिर्हिता
c. A1.घृत; A2.घृति
d. B.धृतिष्ठ॰
A.B.कलाद्विरकिला (B2.॰रकला)

of the intervals as the maximum equation of the centre, and neglecting the correction of the epicycle, we give hereunder the given and computed values for comparison.

Anomaly	15°	30°	45°	60°	75°	90°
Computed intervals	37′ 6″	34′ 36″	29′ 42″	22′ 46″	14′ 20″	4′ 53″
Given intervals	34′ 42″	33′ 55″	30′ 2″	24′ 10″	14′ 16″	6′ 18″

The sum forming the maximum is 143′ 23″, and very near that of the *Pauliśa*, and very much more than the actual. This excessive roughness itself is an indication that the *Siddhānta* is not indigenous. The author has not clearly mentioned where the intervals are to be taken in the given order and where in the reverse order, as also where they are additive and where subtractive. Or, adopting the reading *mithunadalāt*, we can understand that the equation of the centre is subtractive in the six signs of the mean Sun beginning from the middle of Gemini, and therefore additive in the other six. From the corrected reading, *vyutkramaśaśca*, we understand that after taking the intervals in the given order, we take them in the reverse order. From these everything else is inferred.

[स्फुटचन्द्रः]

'खखरूपाष्टगुण'घ्नात् 'कृताष्टन(खै)क'वर्जिताद् द्युगणात् |
'त्रिविषयनवखकृताशा'परिशुद्धान्मध्यशीतां(शु): || ४ ||

'शून्यैकैका'(भ्य)स्ता'न्नवशून्यरसा'न्विताद्दिनसमूहात् |
'रूपत्रिखगुण'भक्तात् केन्द्रं शशिनोऽस्तगमव(न्त्याम्) || ५ ||

'मनु-भव-यम'सहि(तोंऽशो) 'वसुहोता'वर्जी(ते) 'धृति-कृ(ती)' च |
'विषयकृति-रष्टषट्कं' 'नव-तिथि' (रहि)तौ न('ख'-'चन्द्रे'ण) || ६ ||

True Moon

4. The mean Moon in revolutions etc. is got by multiplying the 'day' by 38100, subtracting 10,984, and dividing by 10,40,953.

5. The mean anomaly in revolutions etc. is obtained by multiplying the days by 110, adding 609, and dividing by 3031, the result being for sunset at Ujjain.

6. For the half-signs of anomaly the intervals of equation of the centre are: 1° + 14′ + 25″, 1° + 11′ + 48″, 1° + 2′ − 9″, 48′ − 15″, 48′ − 18″ − 0″, and 48′ − 18′ − 20′ − 1″ (i.e. (1) 1° 14′ 25″, (2) 1° 11′ 48″, (3) 1° 1′ 51″, (4) 47′ 45″, (5) 30′ 0″, (6) 9′ 59″).

4a. B. स्वस्वरूपा॰. A.B. गुणाष्टघ्नात्
b. A.B. क्रताष्ट A.B.C.D. नक्कैक A. वर्जिता द्यु; B. वर्जिद्यु
c. A.B. त्रिविषये च ख॰;. D. विषयाङ्कखकृताशा
d. D. परिलब्धान्मध्य. A.B. शीतांशो:
5a. A.B. ॰क्कान्यस्ता
b. B. समूह्रन्
d. A. ॰मवद्याम्; B1. मवद्गाम्; B2.3. मवदृगाम्
6a. A.B. सहितांशौ
b. C.D. होत्रा A2. वस्तु A.B.C.D. वर्जितो A.B. धृतिकृतौ च; C.D. धृतिकृतश्च
c. A. क्रति A.B. रष्टवषट्कं (B. ट्क); D. रष्टिषट्कं. C. विषयक्रतुरष्टषट्को-
d. A.B. नवप्ति (A2. नवतिहितौ) C. ना षष्टिस्तौ च; D. नवतिहीनं [हि] तं A. चन्द्रेना; B. चन्द्रेन; C. चन्द्रोनौ

The true Moon is got thus:-

(i) mean Moon in revolutions = (days × 38,100 − 10,984) ÷ 10,40,953.

(ii) mean anomaly in revolutions etc. = (days × 110 + 609) ÷ 3031.

This is for sunset at Ujjain. If required for sunset at Yavanapura, 622½ should be used in the place of 609, we shall explain how, later.

(iii) The intervals of equation of the centre for the 6 half-signs in a quadrant are, 1° 14′ 25″, 1° 11′ 48″, 1° 1′ 51″, 47′ 45″, 30′ 0″ and 9′ 59″. In the first quadrant these are to be deducted in the given order, in the second they are to be added in the reverse order, in the third they are to be added in the given order, and in the fourth they are to be subtracted in the reverse order.

(iv) True Moon = (i) + (iii).

Example 2. For days 59, (from sunset at Yavanapura), compute the true Moon.

(i) The mean Moon = (59 × 38,100 − 10,984) ÷ 10,40,953
= Rev. 2-1-23-36-30 = *rā*. 1-23-36-30.
(ii) Mean anomaly = (59 × 110 + 622½) ÷ 3031 = *rā*. 4-4-46.
(iii) The equation of the centre = − 1° 14′ 25″ − 1° 11′ 48″ − 1° 1′ 51″ − 47′ 45″ − 30′ 0″ − 9′ 59″ + 9′ 59″ + 30′ 0″ + 4° 46′ × 47′ 45″ ÷ 15° = −4° 0′ 39″.
(iv) True Moon = (i) + (iii) = *rā*. 1-23-36-30 − 4° 0′ 39″ = *rā*. 1-19-36. (*Note:* This is for sunset at Yavanapura).

The rules are explained as in the case of the Sun thus: In I.15, it has been mentioned that in the *Romaka yuga* of 2850 solar years, there are 1050 intercalary months and 16,547 suppressed *tithis*. Therefrom it has been shown, that in the yuga there are 2850 × 12 = 34,200 solar months, 34,200 + 1050 = 35,250 synodic months, 35,250 + 2850 = 38,100 lunar revolutions, and 35,250 × 30 − 16,547 = 10,40,953 mean solar or civil days. So, from the proportion: If there are 38,100 lunar revolutions in 10,40,953 days, how many are there in the days from epoch, we have, the number of revolutions = days × 38,100 ÷ 10,40,953.

The mean Moon at epoch should be added to the mean Moon or the time by which the Moon completes the current revolution should be omitted from the days. According to the *Romaka*, by 10,984 ÷ 38,100 days after epoch, the mean Moon is a full revolution, though we cannot verify this, as the original *Romaka* is lost. Therefore, we have to deduct from the product of days from epoch, (10,984 ÷ 38,100) × 38,100 = 10,984, as instructed. With the given deductive constant we get that the *Romaka* mean Moon in revolutions at epoch = (0 × 38,100 − 10,984) ÷ 38,100 = *rā*. 11-26-12.

See how close this is to the actual, *rā*. 11-24-48, to the *Saura*, *rā*. 11-25-6, and the *Siddhānta Śiromaṇi's rā*. 11-25-49. This is why we corrected the reading, *kṛtāṣṭanavakaikā* (1984) into *kṛtāṣṭanavakhaika* (10,984). If the reading is taken as it is as done by TS and NP then the mean Moon at epoch would become *rā*. 11-29-19, which is improbable, being too far from the actual. We have also shown under I. 8-10 that the mean Moon of the corrected reading alone would agree with the constants there.

In the *Romaka*, as in the *Vāsiṣṭha-Pauliśa* there are 110 anomalistic revolutions of the Moon in 3031 days. Therefore multiplying the days by 110 and dividing by 3031, the mean anomaly of the Moon in revolutions etc. is got. As, according to the *Romaka* 609/110 days before sunset at Ujjain, it was a full revolution, we have the additive constant 609. We cannot understand why the anomaly alone is given for sunset at Ujjain, while it could also be given for Epoch, i.e. for sunset at Yavanapura by

making the additive constant 622½. That is why in our rules for computation we have given this constant. Perhaps the author wanted to avoid the fraction in the constant. The anomaly computed for Epoch in revolution etc. = (0 × 110 + 622½) ÷ 3031 = *rā*. 9-12-16. Compare this with the actual, *rā*. 9-9-34, *Saura's rā*. 9-9-47, and *Siddhānta Śiromaṇi's rā*. 9-11-23.

The intervals of the equation of the centre are given in minutes and seconds as in the case of the Sun, with the special mention of degrees where there are full degrees. But the text here is so corrupt that we are not certain about the numbers, since the original *Siddhānta* is lost. So we have to depend much on guessing. Adding the intervals we understand that in this *Siddhānta* the Moon's maximum equation of the centre is 4° 55′ 48″. Using this, and not doing the correction to the epicycle, since it is not known, we have computed the intervals and given them hereunder, for comparison with the given values:

Anomaly	15°	30°	45°	60°	75°	90°
Computed Values	1° 16′ 34″	1° 11′ 20″	1° 1′ 15″	47′ 1″	29′ 33″	10′ 5″
Given Values	1° 14′ 25″	1° 11′ 48″	1° 1′ 51″	47′ 45″	30′ 0″	9′ 59″

In the matter of order of taking the intervals and of adding or subtracting them our remarks under the sun hold here too.

[रवि-चन्द्र-भुक्तिः]

'खनवनगाः' शशिभुक्तिः ('कृ)तवसुमुनयः' शशाङ्ककेन्द्रस्य |
यातस्फुटान्तरे दिवसभुक्तिरागामिकी नैशी || ७ |

Daily motion of the Sun and the Moon

7. The daily motion of the mean Moon is 790′, and that of the mean anomaly, 784′. For work relating to the day-time the true daily motion is the difference between the true Moons of the taken day and the previous day. For work relating to the night-time the true daily motion is the difference between the true Moon's of the taken day and the next day.

The true daily motion, given in the second half, pertains both to the Sun and the Moon. The daily mean motions of the Moon and its anomaly alone is given because in the case of the Sun both are the same, practically, equal to 59′ 8″, and well known. It would have been better if the Moon's mean daily motion had been given as 791′. Thus, the following is intended:

(i) To get the true daily motion of the Sun, take the last interval used in obtaining the true Sun, divide it by 15, and apply it to 59′ 8″ as the quantity got from the last interval has been applied to the mean Sun. This can be taken as true daily motion for both the day-time and the night-time as there is not much difference.

(ii) To get the true daily motion of the Moon:

(a) for the day-time work, find from the intervals the equation of the centre for the last 784′ of the anomaly, and apply it to 790′ as the last part of the interval itself is applied.

7a. A1.B1.वनगा
b. A.क्रतव B.तत्तव°. B.शशङ्केन्द्रस्य
c. B.यातः स्फुटा; CD.याता स्फुटा
d. A.B1.2.सभुक्ति आगामि

(b) *for the night-time work, find from the intervals the equation of the centre for the 784′ following*, in the anomaly, and apply it to 790′ as that itself would be applied.

Example 3. The days from epoch is 59, (given in the previous two examples). Find the Sun's and the Moon's true daily motion, for the day gone and the day to come.

(i) In example 1, the last interval used is −33′ 55″. The 15th part of this is −2′ 16″. Applying this to 59′ 8″, the Sun's true daily motion for both days is 59′ 8″ − 2′ 16″ = 57′ (in full minutes).

(ii) In example 2, the Moon's mean anomaly used is *rā*. 4-4-46.

(a) For the day previous, the last 784′ of this begins from *rā*. 3-21-42. The equation of the centre pertaining to this part of the anomaly = + 30′ × 8° 18′ ÷ 15° + 47′ 45″ × 4° 46′ ÷ 15° = + 16′ 36″ + 15′ 10″ = + 31′ 46″, (say + 32′). Applying to the mean motion, 790′, the true motion for the previous day = 790 + 32 = 822′.

(b) For the next day, we have to find the equation of the centre for anomaly from *rā*. 4-4-46 to *rā*. 4-17-50. This is equal to, + 47′ 45″ × 10° 14′ ÷ 15° + 1° 1′ 51″ × 2° 50′ ÷ 15° = + 32′ 35″ + 11′ 41″ = + 44′ 16″. Applying to the mean motion, the daily motion for the day following = 791′ + 44″ = 835′.

The instruction is easy to understand, for, clearly the difference in the longitudes of two consecutive days is the motion for the day. As, in the *Romaka*, the day begins at sunset for which the longitude is computed, the day-time before sunset falls in the day previous, and the night following sunset falls in the day next. Hence for work in each, respectively, the motion for the previous day and the next day has to be taken. To avoid computing the longitudes of both days, we have given an easy method, which should have been intended by the author also, for, otherwise, he need not have given the mean motions of the Moon and its anomaly.

[राहुः]

'त्र्यष्टक'गुणिते दद्याद् 'रसर्तुयमषट्कपञ्चकान्' राहोः ।
'भवरूपाग्न्यष्टि'हते क्रमात् झषान्तो(च्चयु)ते वक्त्रम् ॥ ८ ॥

Rāhu

8. Multiply the days from epoch by 24, add 56, 266 and divide by 1,63,111. Subtract the revolutions etc. obtained, from the end of Pisces, (i.e. from any whole number of revolution). The Head of Rāhu is obtained.

The following is instructed to be done:
(i) Revolutions etc = (days × 24 + 56,266) ÷ 1,63,111
(ii) Head of Rāhu = *rā*. 12-0-0 − Revolutions etc, omitting the full revolutions.

8a. B. त्र्यष्टगुणिते
b. A. नाहोः
c. A1. रूपानन्यष्ठि
d. A. क्रमाझखांत्तोव्यते; B. क्रमादुखान्तोच्चते (B2. क्रमातु दु°); C. क्रमात् झषान्तोत्क्रमात् वक्रम्
D. क्रमात् झषात् सोच्यते

Example 4. Compute Rāhu for the moment, 59 days from epoch.

(i) Revolution etc. = (59 × 24 + 56,266) ÷ 1,63,111 = *rā.* 0-4-7-19.

(ii) Head of Rāhu = *rā.* 12-0-0 – *rā.* 4-7-19 – *rā.* 7-22-41.

From this the tail = *rā.* 7-22-41 + *rā.* 6-0-0 = *rā.* 1-22-41.

We have said that the Moon's node is called Rāhu, on account of the connection between the two. Of the two nodes, the first is the Head and the second, situated six signs away, is the Tail of Rāhu. According to the *Romaka*, there are 24 revolutions of the Moon's nodes in 1,63,111 days. Therefore, multiplying the days by 24 and dividing by 1,63,111 the revolutions are got. As the motion is retrograde, what is obtained has got to be treated as negative, and therefore to be subtracted from 12 signs or full revolutions. At the moment 56,266/24 days before Epoch, the Head of *Rāhu* was a full revolution, and in order to reckon from that time 56,266 is added to the days multiplied by 24.

As for the correctness of the numbers, we cannot verify them since the original is lost. But we can see how nearly correct the *Romaka* Rāhu here given is, by comparison with that of other systems. At Epoch the Head or Rāhu according to the *Romaka* = *rā.* 12-0-0 – (0 × 24 + 56,266) ÷ 1,63,111 = *rā.* 7-25-49. Actually it is *rā.* 7-26-0. According to the *Pauliśa* it is *rā.* 7-25-59, and according to the *Saura*, *rā.* 7-26-6. The time for one tropical revolutions is 1,63,111 ÷ 24 = 6796-17-30 days. The correct time is 6798-21-48. The difference of 2-4-18 days is caused by the wrong constant of precession adopted by the *Romaka*, of 34″ instead of the correct 50″. Thus, since the *Romaka* precession is less by five minutes in the time taken by one revolution, its period of revolution must be about two days less as it is found to be, and the disagreement is small indeed.

[लम्बनम्]

दिनमध्यमसंप्राप्ता यावत्यो नाडिका व्यतीता वा |
ताभ्यः षड्गुणिताभ्यो ज्यात्रिंशां'शस्तिथेर्नाम[:] || ९ ||

Parallax in longitude

9. (This is the same as VII.1. and explained completely there. There is no difference in meaning between the readings there and here, *dinamadhyama-samprāpyā* and *dinamadhyamasamprāptā*).

[दृक्क्षेपः]

उदयात् प्रभृति च नाड्यो याः स्युः प्राग्लग्नमानयेत्ताभिः |
तस्मात्तु नवसमेतादपक्रमांशान् विनिश्चत्य || १० ||

लग्नत्र्यगुविवरज्यां द्विगुणां स्व'रसां'शसंयुतामपमात् |
जह्याद् दिग्व्यत्यासे विक्षेपैक्ये तयोर्योगः || ११ ||

9. Quoted by Utpala on *BS* 5.18
9a. B. मध्यसमं प्राप्ता
b. B. यायत्या. A. त्यो दिनाधिका
c. B. षट्गुणिता योज्या
d. A.B. तिथिर्नाम; C. तिथेर्नाम

उत्तरमक्षाच्छुद्धं याम्यं साऽक्षं च दक्षिणं विद्यात् |
उत्तरमक्षाद्यदधिकमुत्तरमेवं विजानीयात् || १२ ||

Declination of the Nonagesimal

10. At any time (for which the zenith distance of the nonagesimal, ZDN, is desired,) find the orient ecliptic point, OEP. Add nine signs to it. (This point is called the nonagesimal). Find its declination.

11. Subtract the Head of Rāhu from the nonagesimal, find its sine, double it, and add a sixth of the quantity got by doubling, (i.e. find the latitude of the Moon, supposing it to be situated at the nonagesimal). Add this to the declination found above if both are of the same direction, and subtract it from the declination if they are of different directions. (Thus the declination of the nonagesimal is corrected).

12. The north declination, being less and therefore deducted from the latitude of the place, the remainder (which is the ZDN) is south. The south declination must be added to the latitude, and the sum (forming the ZDN) is north. The part of the north declination greater than the latitude, (i.e. the remainder after deducting the latitude from the north declination, which forms the ZDN), is north.

Lagnatryaguvivara actually means the difference between the OEP and the Head of Rāhu, plus three signs. Clearly this is equal to the difference between the nonagesimal and the Head of Rāhu, as translated above. Therefore, if the reading, *lagnāsuravivara* is adopted, the word *lagna* must be taken to mean *tribhonalagna* or nonagesimal. If the nonagesimal is greater than the Head and less than the Tail, the latitude obtained is north, otherwise south. Why this is so has been explained in connection with finding the Moon's latitude according to the *Pauliśa*. Though, in a general way, the nonagesimal latitude is asked to be deducted from the declination if of different directions (instruction contained in verse 11), in the case where the declination is less, the declination is to be deducted from the latitude, the direction of the corrected declination being the direction of the latitude. The instructions contained in verse 12 envisages only places north of the equator, as usual.

10-12, Quoted by Utpala on *BS* 5.18

10a. A.व for च
b. B.याः पुः प्रालग्नमानये ताभिः
c. A.B1.नवमसेता
d. A.C.D.॰मांशा; B.॰माशात्
A.B.विनिश्चत्या (B2.॰त्यं); C.D.विनिश्चिन्त्याः

11a. A.वग्रासुरविरज्यां; B.C.लग्नासु (B3.लग्नास) रविरत्यां;
D.लग्नासुर वि [व] रज्यां
b. A1.C.सवसांस; B1.2.यासां स;
B2.सारसां; D.स्वरसाप्तामपक्रमांशात् |
A1.संयुतममरान्; | B.संपुतयममरान्
c. A.B.जह्या दिग्व्यत्यासौ
d. A.B.विज्ञेयैके

12a. B.मक्षाच्छुर्द्धं
b. B.य for च
C.U.विन्द्यात्
c. B.उत्तमक्षां

Thus, the following has got to be done:

(i) The OEP for the time for which the parallax corrected latitude is required, is found, by using the local ascensional differences.

(ii) Nonagesimal = OEP + 9 signs.

(iii) Find the declination of the nonagesimal, marking its direction north or south.

(iv) Sine (nonagesimal − Head of Rāhu) × 7/3 = latitude pertaining to nonagesimal. This is north if (nonagesimal − Head of Rāhu) is within 6 signs, south otherwise.

(v) Corrected declination = declination ± latitude, found in (iv), (the upper sign of same direction, otherwise lower, the direction of the result being that of the greater.

(vi) ZDN = Latitude of the place ± corrected declinations, the upper sign if the corrected declination is south, lower sign otherwise. In the latter case, if the latitude is greater, the direction of ZDN is south, if the declination is greater it is north).

The work is thus explained: In computing the solar eclipse it has been mentioned under VII.1, that in the place of the Moon's latitude, the same corrected for parallax has got to be used. To get the correction the sine of the ZDN is required. For ease of computation, the *Romaka* takes the difference between the latitude of the place and the declination of the nonagesimal (the directions being taken into consideration,) as the ZDN, the error being small as can be seen from the figure under VII.1. This is given by verse 12 above.

Further, the parallax correction for latitude depending on sine ZDN is on the supposition that the Moon moves on the ecliptic, which is only approximately true. Actually the Moon moves in its orbit, and a small correction has got to be made for this, and the work of verse 11 above is intended for this. Practically, all astronomers before the famous Bhāskarācārya II have given this rule, on the surmise that taking a point on the Moon's orbit, corresponding to the nonagesimal, things will be all right. But the mistake in this has eluded all these ancient astronomers, including the astute Brahmagupta. It was Bhāskarācārya who detected their mistake, showed, by means of an example, how the rule was wrong, and gave the correct rule. (Vide the *Vāsānā-Bhāṣya* at the end of *Sūrya-grahaṇādhikāra, Gaṇitādhyāya, Siddhānta Śiromaṇi).*

From the rule given by verse 11, it can be inferred that according to this *Siddhānta* the obliquity of the Moon's orbit, giving the maximum latitude of the Moon, is 280 minutes, (got from: 120 × 2 (1 + 1/6) = 120 × 7/3 = 280). We shall see that this agrees with the rule given by verse 14, giving the Moon's latitude. But TS have adopted the incorrect reading, *kharasāṃśasammitām* and dividing the doubled sine by sixty, got the latitude, which they are constrained to consider to be in degrees. NP too, accept the same sense as TS with an emended reading *kharasāptām apakramāṃśāt*. By this the maximum latitude according to the *Romaka* would be 4°. It is very strange that they do not see this is too far from the correct value, highly improbable in the *Romaka* which they themselves praise inordinately, and disagrees with their own (TS's) commentary under verse 14.

[नतिः बिम्बमानं च]

तज्ज्याघ्नीं शशिभुक्तिं हृत्वा 'धृतिभिः शतैः' स्मृता [ऽवनतिः] |
मध्यममानं त्रिंशद् भानोः शशिनश्चतुस्त्रिंशत् || १३ ||

Parallax correction and orbital diameter

13. Multiply the true daily motion of the Moon by the sin of ZDN, thus found, and divide by 1800. This is the parallax correction for latitude. The mean angular diameter of the Sun is 30 minutes, and that of the Moon, 34 Minutes (according to the Romaka).

Thus:

(i) Parallax in latitude = sine corrected ZDN × true daily motion of the Moon ÷ 1800 (Its direction is that of the ZDN).

(ii) Mean angular diameter of the Sun = 30′.

(iii) Mean angular diameter of the Moon = 34′.

(Using (ii) and (iii) the respective true angular diameters are to be found).

Under VII.1, it was explained that the parallax correction for latitude, to be used in the solar eclipse, is obtained by multiplying the horizontal parallax of the Moon relative to the Sun, by the sine of the ZDN and dividing by 120, (the max. sine). It was also shown there that the horizontal parallax itself varies inversely as the distance of the Moon from the earth, being greatest when the Moon is nearest. Hindu astronomers take it that the distance is inversely proportionate to the true daily motion, though this is only approximately correct. Therefore it is taken here that the relative parallax is proportionate to the motion, the Sun's parallax being very small compared to that of the Moon. Here, the parallax correction i.e. relative horizontal parallax × sin (corrected) ZDN ÷ 120 = Moon's daily motion × sin (corrected) ZDN ÷ 1800. From this it can be seen that according to this *Siddhānta*, the relative horizontal parallax is the daily motion divided by 15. Therefore the mean relative horizontal parallax = 790′.5 ÷ 15 = 52.7 minutes, as mentioned already. As for the mean angular diameters that is what the *Siddhānta* has found them to be, by observation or analysis of eclipses.

समलिप्ता(ऽगु)विवरज्या[ऽभ्य]स्ता 'मूर्च्छना' नवहृताश्च |
अवनत्यायुतविश्लेषिताश्च दिक्साम्यवैलोम्ये || १४ ||

14. Twentyone, multiplied by the sine of (Sun or Moon at new moon ~ Rāhu) and divided by nine is the latitude. This, with the parallax correction added is the parallax-corrected latitude, when both are of the same direction. When of different directions, their difference is the corrected latitude.

13. Quoted by Utpala on *BS* 5.18

13a. A. तज्यार्ग्नीं; B1. तज्याग्नी; B2.3. तज्याग्री

b. B. शनैः. A. B1.2. स्मृता नवभिः; D. स्फुटावनतिः

c-d. B. त्रिशन्दानोः

d. A. °स्त्रिंशत्र; B1.3. °स्त्रिशन्

14. Quoted by Utpala on *BS* 5.18

14a. A. लिप्ताद्गविवर; B. लिप्तिताद्र विवर;
C.D. U. लिप्ताराहुविवर

b. A.B1.2. न्यस्ता. D. हृता च

c. A. अनवद्या; B. अवनधा
B. विश्लि

d. B. षिवाश्च; D.U. षिता च. A1.B1. साम्ये; A2. सान्ये

It is stated here that,

(i) The Moon's latitude at new moon = sin (Moon ~ Rāhu) × 7 ÷ 3.

(ii) Parallax-corrected latitude = Moon's latitude ± parallax correction given in verse 13. (The upper sign is to be taken if both are of the same direction, and the lower sign, if of different directions, the resulting direction being that of the greater).

The latitude at new moon is the distance of the Moon north or south of the Sun, as seen by an observer at the centre of the earth. For an observer on the surface, there is a difference in this, equal to the parallax in latitude. Therefore they have to be combined, taking the directions into consideration, to find the actual distance as observed, *i.e.* if of the same direction they have to be added, and if of different directions the differences is to be taken, the direction being that of the greater. Though the author wants this to be done at new moon, as the use of the word *sama-lipta* indicates – perhaps following the instructions of the original *Siddhānta* – it will be better if it is done at new moon corrected for parallax in longitude, that being generally nearer the circumstances.

It is given that the sine of (Moon ~ Rāhu) multiplied by 21 and divided by 9, (it will be easier to multiply by 7, and divide by 3), is the latitude. From this, the maximum latitude according to this *Siddhānta* = the maximum sine × 7 ÷ 3 = 120′ × 7 ÷ 3 = 280′. This agrees with verse 11 above, as already said. But TS say here that the maximum is 270′, contradicting their statement under verse 11, that it is 4°, i.e. 240′. Without any reason, they assume here that the maximum is 270′, and since the maximum sine multiplied by 21 and divided by 9 does not give 270′, they say that the multiplier and the divisor given are approximate!! The same applies also to NP, vide their derivation (pt.II, p.63) of the result "i ≈ 4° .... (3c)" and "i ≈ 4:30° ... (10), in contrast to (3c)" (pt.II. p.64). Further, TS's statement, that the parallax due to the Sun has been omitted by the author on account of its smallness, is wrong, for the intention of the author is only to give the relative parallax. The correct statement would be, "The Sun's parallax has not been separately computed and deducted from the Moon's, as the difference in effect would be negligible".

[स्फुटबिम्बमानम्]

मध्यममानाऽभ्यस्ता स्फुटभुक्तिर्मध्यभुक्तिभक्ता च |
भवति कलापरिमाणं तत्कालीनं रविहिमांश्वोः || १५ ||

True diameter of the orbs

15. The mean angular diameters of the Sun and the Moon, respectively, multiplied by their true daily motions and divided by their mean daily motions, gives the true angular diameters at the time of eclipse.

Thus:

(i) The angular diameter of the Sun = 30′ × Sun's true daily motion ÷ 59.

(ii) The angular diameter of the Moon = 34′ × Moon's true daily motion ÷ 791.

15. Quoted by Utpala on *BS.* 5.18
15a. A.०मभाना०. A.B.न्यस्ता
b. A.भुक्तिमध्यमभुक्ति; B1.2.भुक्तिमभुक्ति; B3.स्फुटभक्तिमध्यमभुक्तिमत्ता च
c. A.B.कलापपरि. B2.परिमानं
d. B1.2.हिमांशोः;

It is a matter of experience that an object looks bigger, the nearer it is, smaller the farther away it is, i.e. the angle formed by the object at the eye is inversely proportionate to the distance. We have already mentioned that approximately the daily true motion of the Sun and the Moon is inversely proportionate to the distance. Therefore, the angle at the eye is proportionate to the daily true motion, approximately. Hence, from the proportion, Mean motion: True motion:: Mean angular diameter; True angular diameter, we have,

True angular diameter = Mean angular diameter × true motion ÷ mean motion,

which is the rule given.

[ग्रहणकालः]

अवनतिवर्गं जह्याद् रवीन्दुपरिमाणयोगदलवर्गात् |
तन्मूलात्तु द्विगुणात् तिथिभुक्तवदादिशेत् कालम् ||१६ ||

Moment of the eclipse

16. Subtract the square of the parallax-corrected latitude from the square of the sum of the semi-diameters. The square root of the remainder, multiplied by two, is the number of minutes of arc giving the duration. These minutes, multiplied by 60 and divided by the minutes of relative true daily motion gives the time of duration in *nāḍikās*.

The following is to be done:

(i) Minutes of arc of duration = $2\sqrt{(\text{sum of the semi-diameters})^2 - (\text{parallax corrected latitude})^2}$.

(ii) Time duration in *nāḍis* = minutes of arc of duration × 60 ÷ daily relative true motion in minutes of arc. (Half this, subtracted from, and added to the time of new moon corrected for parallax gives the first and last contacts respectively).

The rationale of the work has been shown in connection with the *Pauliśa* (chap. VII). We must add the following: If the latitude as corrected for parallax is found separately, each for the time of first contact and the time of last contact, and used in the work, then each will be more correct. Thus, the corrected latitude and the time are interdependent, each requiring the other for its computation, and therefore the method of successive approximation is indicated here. This is not mentioned by the work, as being easily understood, or the author does not give it because it is not found in the original.

[ग्रहणपरिलेखः]

रविशशिमानयुतिदलादवन[ति]हीनाद्भवन्ति या लिप्ताः |
तान्यङ्गुलानि विद्याद् भानोश्छन्नानि चन्द्रमसा || १७ ||

16. Quoted by Utpala on *BS* 5.18
16a. A1.B1.2.वर्ग्रं; A2.वग्र
b. A.रविन्दु. B.॰दलवग्रति
c. A.॰मलात्तु. B.द्विगुणा

अर्धेनाऽऽलिख्य रविं दत्वाऽवनतिं यथादिशं मध्यात् ।
अवनत्यन्ताच्चन्द्रं विलिखेद् ग्रासार्थमर्धेन ॥ १८ ॥

Eclipse diagram

17. Subtract the parallax-corrected latitude for the time of parallax-corrected new moon, from the sum of semi-diameters. The remainder in minutes are the digits of obscuration of the Sun by the Moon.

18. To represent the amount of obscuration graphically, draw a circle of radius equal to the semi-diameter of the Sun, measure the parallax-corrected latitude north or south according as where the Moon is situated, and with the point marking its end as centre draw a circle of radius equal to the Moon's semi-diameter, to represent the Moon. (The part common to both the circles is the part obscured, and its measure in digits is its width in minutes of arc.)

Obscuration in digits = Sum of the semi-diameters, in minutes − parallax-corrected latitude, in minutes. (This for the time of parallax-corrected new moon).

The Fig. to illustrate this is given at the end of *Example 5*, as part thereof. It can be seen from there that the amount of obscuration, AB = SB − SA = SB − (SM − MA)

= SB + MA − SM

= radius of the Sun + radius of the Moon − corrected latitude

= sum of the semidiameters − corrected latitude.

The author has taken it that one minute of arc appears to the eye as one digit, though actually the apparent size varies, ('apparent' because this is an illusion), the heavenly bodies appearing to be bigger the nearer they are to the horizon.

Example 5. After 59 days has passed from epoch, on the 60th day, there is a solar eclipse. Compute this for Pudukkottai (in S. India) (lat. 10° 23'; longitude 48° east of Yavanapura, represented by 8 nāḍis of time).

The first things to be found are: The Sun and Moon at new moon, the daily motion etc. In *Example 1*, we have found that the true Sun for 59 days from epoch is *rā.* 1-28-24. In *Example 2*, the true Moon is found to be *rā.* 1-19-36. In *Example 3*, the Sun's true daily motion for the 60th day is found to be 57′, and the Moon's, 835′. In *Example 4*, the Head of Rāhu is found to be *rā.* 7-22-41. (All the three longitudes are for mean sunset at Yavanapura, that being the time of day of epoch.) Sun − Moon = *rā.* 1-28-24 − *rā.* 1-19-36 = 8° 48′. The Sun being greater, the new moon is to come.

The relative daily motion = the difference of the true motions

= 835′ − 57′ = 778′.

17a. B1.2.°दवनिति. A.भवन्ति
c. A.C.D. U.विंद्यात्
d. A.भानो छन्नानि. A1.चंद्रममसा; A2.चंद्रमदमस्म

18a. B.अद्वनालिख्य रवि
b. B.1.2.दंत्रा. A.B1.2.नवतिं
c. A.यांतश्चंद्रं; B.यातश्चन्द्रं
d. B.विलिखेतु ग्रासार्द्धे

The *nāḍis* of new moon from mean sunset at Yavanapura, = 60 × 8° 48′ ÷ 778′ = *nā*.40-43.

The time of new moon from mean sunset at Pudukkottai =*nā*.40-43 + *nā*.8-0 = *nā*.48-43.

i.e. on the 60th day, after mean sunrise at Pudukkottai, the new moon is at *nā*.48-43 − *nā*.30-0 = *nā*.18-43. Given the half-*cara* for the day, 39 *vināḍis*, the new moon is at *nā*.18-43 + *vi*.39 = *nā*.19.22. (No correction is made for equation of time since the Siddhānta does not give it.)

At new moon, the Sun = the Moon =*rā*.1-28-24 + 48′ = *rā*.1-29-12.

Head of Rāhu at new moon = *rā*.7-22-41 − 2′ = *rā*.7-22-39.

Correction of new moon for parallax (by verse 9.):

Half day-time is *nā*.15-0 + *vi*.39 = *nā*.15-39.

The time elapsed after noon = *nā*.19-22 − *nā*.15-39 = *nā*.3-43.

Corresponding to this, there are 22° 18′.

Sine 22° 18′ = 45′ 32″.

The parallax bending of the new moon, (later) = 45′ 32″/30 = *nā*.1-31.

Parallax-corrected new moon = *nā*.19-22 + *nā*.1-31 = *nā*.20-53.

The OEP at new moon: The required ascensional difference for every *Drekkāṇa* for Pudukkottai in *vināḍis* are 90, 94, 98 for Taurus; 102, 105, 108 for Gemini; 109, 110, 109 for Cancer; 108, 105, 103 for Leo; 101, 101, 99 for Virgo. The new moon is 1162 *vināḍis* from sunrise. 8 *vināḍis* after sunrise Taurus ends, 315 from this Gemini ends, 328 from this Cancer ends, and 316 from this Leo ends. For the remaining 195 in Virgo, the part risen is 10° + 9° 18′ = 19° 18′.

∴ *OEP* = *rā*.5-19-18.

Nonagesimal = OEP +*rā*.9-0-0 = *rā*.2-19-18.

sin declination of nonagesimal = 48′ 48″ × sine (*rā*.2-19-18) ÷ 120′ = 47′ 58″.

Declination = 23° 33′, North.

Corrected declination of the Nonagesimal (verses 10-11) Nonagesimal ~ Head of Rāhu = *rā*.2-19-18 ~ *rā*.7-22-39 = *rā*.6-26-39.

Sine of this = sin *rā*.0-26-39 = 53′ 49″.

53′ 49″ × 2 (1 + 1/6) = 126′, south, (since the Nonagesimal is more than 6 *rāśis* distant from Head of Rāhu).

Being of different directions, 23° 33′ − 126′ = 21° 27′, North is the corrected declination.

Z D N (by verse 12) : corrected declination − latitude = 23° 27′ − 10° 23′

= 11° 4′, north (being north declination and greater than latitude).

Parallax in latitude (by verse 13) = Sin Z D N × Moon's true daily motion in minutes ÷ 1800 = 22′ 50″ × 835 ÷ 1800 = 10′.6, north, (same direction as Z D N).

The uncorrected latitude at new moon = (verse 14):

Moon − Head of Rāhu = *rā*.1-29-12 − *rā*.7-22-39

= *rā.* 6-6-33.

Sine *rā.* 6-6-33 = Sin 6° 33′ = 13′ 41″.

The latitude = 13′ 41″ × 7/3

= 31′.9, south, (the Moon being more than 6 *rāśis* distant from Head of Rāhu).

Parallax-corrected latitude = (by verse 14), 31′.9 − 10′.6 = 21′.3, south.

Sum of true semi-diameters (by verse 15) :

True diameter of Sun = 30′ ×57 ÷ 59 = 29′.

True diameter of Moon = 34′ × 835 ÷ 791 = 35′.9.

Sum of semi-diameters = (29′ + 35′.9)/2 = 32′.4.

Duration (by verse 16):

Minutes of arc of duration = $2 \times \sqrt{32.4^2 - 21.3^2} = 2 \times 24'.4 = 48'.8$.

Time of duration = 48′.8 × 60 ÷ 778′ = *nā.* 3-46.

Half duration = *nā.* 1-53.

Subtracting this from parallax-corrected new moon, first contact is, *nā.* 20-53 − *nā.* 19-0, after sunrise.

Adding to parallax-corrected new moon, last contact is, *nā.* 20-53 + *nā.* 1-53 = *nā.* 22-46, after sunrise.

Part obscured in digits (by verse 17): sum of semi-diameters − parallax-corrected latitude = 32.4 − 21.3 = 11.1.

Graphical representation of obscuration

S = centre of the Sun

M = centre of the Moon

SM = parallax-corrected latitude

AB = the measure of the obscuration = 1″.11 = 11.1 digits.

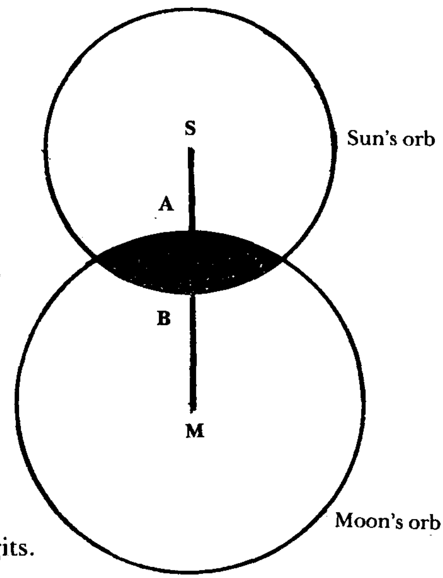


Fig. VIII. 1

In this work, I.8-10 give the 'days from epoch' according to the *Romaka;* I.15, gives the elements concerning the Sun and Moon in the *Romaka-yuga;* VIII.1-8 give the true Sun, Moon and Rāhu; and VIII.9-18 give the solar eclipse according to the *Romaka.* It is the 'days of epoch' of *Romaka* that is intended to be used everywhere in the work; since it is the distance between two points of time and therefore the same by whatever *siddhānta* it is computed. The difference caused by the time of the day like 'Sunset of Ujjain', 'Noon at Ujjain' etc. will, of course, be there, and must be taken into account. The agreement between I.8-10, I.15, and VIII.1-7, each to each, has been shown in the proper places. We have also shown that the Sun, Moon and Rāhu of the *Romaka* are tropical, though the author has not mentioned this specifically. The work being a manual, intended to be used not for a long period, the difference caused by precession is neglected, no reference being made to it. The periods being tropical, itself indicates that this *Siddhānta* is foreign. The Sun's

maximum equation of the centre, given as 143′, also in an indicator, agreeing as it does with Ptolemy's. Though the Moon's maximum equation of the centre given is 296′, and Ptolemy's is 301′, and thus there appears to be a difference, we are not sure that the given quantity is 296′, on account of the extremely corrupt nature of the text in the concerned part. There are also lacunae in the computations intended by the author, which are to be supplied from the *siddhāntas* dealt with already or known otherwise. The method of computing the true Sun and Moon given here is an improvement on the *Pauliśa.*

Only the solar eclipse is dealt with here. The lunar eclipse is omitted probably because it is not different from that of either the *Pauliśa* and *Vāsiṣṭha* given, or the *Sura to be given.* In contrast with the primitive method of the Pauliśa, the *Romaka* method of computation of the solar eclipse is far advanced, and almost the same as that of the later *siddhāntas* like the *Āryabhaṭīya* or the *Saura*. For instance, the parallax in latitude is correctly sought to be computed by using sine ZDN, though the ZDN itself is approximate, being got by combining the latitude of the place and the declination of the nonagesimal. Only the method given for correcting the declination for the nonagesimal to compensate for the Moon being situated on its own orbit instead of the ecliptic, is wrong, as commonly seen in works of authors prior to Bhāskarācārya II. Making the parallax in latitude and the Moon's true angular diameter depend on the Moon's true motion, and the Sun's true angular diameter on the Sun's true motion, is in accordance with the later *siddhāntas,* though giving the respective mean diameters as 34′ and 30′ is very rough. The first contact, middle, and last contact, as also the directions of the points of contact, are intended to be taken from the *Vāsiṣṭha-Pauliśa*, not being given here. The omission of the total or annular phases does not matter, since they cannot be got correctly by the rough methods given. Further, let us not mind the omission of the successive approximation to be done in the computation of the circumstances, though necessary as shown. (This may be because it is not found in the original or easily understood to be necessary). But it will certainly be better to use in the computation the parallax-corrected latitude of the new moon corrected for parallax, instead of that of the uncorrected new moon as given by the text, the former being generally nearer the time of the thing computed. We do not know why the author has not said so. Inspite of all this, the *Romaka* is interesting as being comparatively more ancient, and forming a link between the earlier and the later *Siddhāntas.*

[इति पञ्चसिद्धान्तिकायां वराहमिहिरविरचितायां
रोमकसिद्धान्तेऽर्कग्रहणमष्टमोऽध्यायः ||] [1]

1. Col. A. रोमकसिद्धान्तेऽर्कग्रहणमष्टमष्टमोध्यायः;
B.C.D. इति रोमकसिद्धान्तेऽर्कग्रहणमष्टमोऽध्यायः

Thus ends Chapter Eight entitled 'Romaka-Siddhānta: Solar Eclipse' in the Pañcasiddhāntikā composed by Varāhamihira

Chapter Nine

SAURA-SIDDHĀNTA — SOLAR ECLIPSE

९. नवमोऽध्यायः
सौरसिद्धान्तः — रविग्रहणाम्

Introductory

In the first portion of this chapter the Sun, Moon and Rāhu according to the *Saura Siddhānta* are given, and in the latter portion, the computation of the solar eclipse according to the same. In agreement with the author's statement in his Introduction to the *PS*, that the *tithi* got by the *Saura* is very accurate, we see that not only the *tithi* but most other constants as well are wonderfully accurate, and approximate closely to the modern values. Among the five *Siddhāntas* this is the only one that uses epicycles to compute the Equation of the centre of the Sun and the Moon, and later in chapter XVII, the Equation of the centre and equation of conjunction of the 'star-planets', followed later by astronomers like Āryabhaṭa. The *Ārdharātrika-pakṣa* of Āryabhaṭa, expounded by Brahmagupta in his *Khaṇḍakhādyaka*, follows this *Saura-Siddhānta* in its constants. Though the computation of Days from Epoch ('days') has not been specially given for the *Saura*, (the rule given in I.13 not being clear whether it is related to the *Saura* or not), yet from the *Yuga*-elements of the *Saura* in I.14, it is possible to formulate rules for 'Days from Epoch', following the *Saura*, as has been shown by us in our Notes under I.14. We have also explained how the 'days from Epoch' obtained from the *Romaka* or *Pauliśa* rules can be used for the *Saura* also, provided we bear in mind the variation in time of commencement of the Epoch, as for instance, that the epoch for the mean Sun and Moon, their apogees, and the Moon's node is for mid-day at Ujjain, and for the star-planets it is mid-night.

Now, the author, intending to deal with eclipses, gives first the Sun, Moon and Rāhu on which eclipses depend, beginning with the mean Sun.

[रविमध्यम्]

द्युगणेऽर्कोऽष्टशतघ्ने विपक्ष'वेदार्णवे'ऽर्कसिद्धान्ते |
'स्वरखाऽश्विद्विनवयमो'द्धृते क्रमाद्दिनदलेऽवन्त्याम् || १ ||

Mean Sun

1. According to the *Saura-Siddhānta*, to get the mean Sun in revolutions etc., multiply the days from Epoch by 800, deduct 442, and divide by 2,92,207. This is for Ujjain mean noon.

1. Paraphrased by Utpala or *BS* 2, p.65.

1a. A.B1.णेर्केष्ट. A2.शतघ्नो

c. A.B1.2.॰खाद्विधिनव॰; C.॰खाद्विद्विनव॰

d. A.द्धृते; B1.2.धृते. A2.दिनं. A1.॰वत्यां; B.॰वत्या

That is, take the days from Epoch got by the *Romaka* or *Pauliśa* rule.

The mean Sun at Ujjain mean noon, just preceding the Epoch, (i.e. sunset at Yavanapura beginning Monday),

= (days × 800 − 442) ÷ 2,92,207, in revolutions etc.

Example 1 (a). Find the mean Sun, given days from epoch, 5,28,931. (This is midday, Ujjain, 21-5-1953 A.D.). (b) Get the mean Sun for Ujjain mean noon, just preceding the Epoch, i.e. for zero day. What is it at Epoch, i.e. sunset at Yavanapura?

(a) Mean Sun = (5,28,931 × 800 − 442) ÷ 2,92,207 = revol. 1448-1-5-15.7 = *rā* 1-5-15.7.

(b) Mean Sun at Ujjain mean noon preceding Epoch = (0 × 800 − 442) ÷ 2,92,207 = − 32′.7 = *rā* 11-29-27-3.

Since mean sunset at Yavanapura is *nā.* 7-20 later than that at Ujjain, the mean motion for *nā* 22-20, about 22′, has to be added, and the required mean Sun at Epoch is *rā.* 11-29-49.3. (According to modern astronomy it is 11-29-37.2, assuming that at that period the vernal equinox coincided with the First point of Meṣa. *See how accurate the value is.)*

The rule is explained thus: We showed under I.14 that in the *Saura yuga* of 1,80,000 years, *i.e.* 1,80,000 mean solar revolutions, there are 6,57,46,575 days. Therefore, the revolutions for the given days = days × 1,80,000 ÷ 6,57,46,575 = days × 800 ÷ 2,92,207, reducing the numerator and denominator by the factor 225. Now, according to the *Saura,* the revolution of the mean Sun was completed 442/800 days after Ujjain mean-noon prior to Epoch. Therefore 442 eight hundredth parts have to be subtracted from the total number of eight-hundredths, and hence the deduction of 442. Though the original *Saura* is not obtainable now, yet from the *Ārdharātrika* system of Āryabhaṭa, and the *Khaṇḍakhādyaka* following it, we can see that 442/800 day after the said Ujjain-mean noon the mean Sun's revolution was completed. The Epoch was near the end of *Śaka* 427, i.e. 427 + 3179 = 3606, Kali years gone. Kali began with Friday, Ujjain mean mid-night. For 3606 revolutions, the days (from the beginning of Kali) = 3606 × 2,92,207 ÷ 800 = 13,17,123 42/800. Dividing out by 7, we have the remainder 3 42/800, i.e. 42/800 days after midnight ending Sunday, the revolutions was complete. Since Sunday mid-day is half a day or 400/800 day earlier than midnight, it is 42/800 + 400/800 = 442/800 day earlier, than the time of full revolution, as we have taken and used. Incidentally, we also got that it is Sunday mean noon, agreeing with the fact that the Epoch is at sunset at Yavanapura on that day. Further, we get that according to this *Siddhānta* the length of the year is 2,92,207 ÷ 800, days = 365 - 15 - 31.5 days.

[चन्द्रमध्यं उच्चं च]

नवशतसहस्रगुणिते 'स्वरैकपक्षाम्बरस्वरर्तूने' |
'षट्छून्येन्द्रियनववसुविषयजिनै'र्भाजिते चन्द्रः || २ ||

नवशतगुणिते दद्याद् 'रसविषयगुणाम्बरर्तुयमपक्षान्' |
'नववसुसप्ताष्टाम्बरनवाश्वि'भक्ते शशाङ्कोच्चम् || ३ ||

'शशिविषय'घ्नानीन्दोः '(क्र)कांग्नि'हृतानि मण्डलानि ऋणम् |
स्वोच्चे 'दि(ग्घ्ना)'नि धनं 'स्वर(रन्ध्र)यमो'द्धृते विकलाः || ४ ||

Mean Moon

2. Multiply the Days by 9,00,000, deduct 6,70,217, and divide by 2,45,89,506. The approximate mean Moon in revolutions etc. is got.

3. Multiply the Days by 900, add 22,60,356, and divide by 29,08,789. The approximate Moon's apogee in revolutions etc. is obtained.

4. Multiply the revolutions of mean Moon by 51, and divide by 3121. The resulting seconds of arc are to be subtracted to get the exact mean Moon. Multiply the revolutions of apogee by 10 and divide by 297. The resulting seconds are to be added to get the exact apogee.

The following are the formulae:

(i) Mean Moon in revs. etc = (Days × 9,00,000 − 6,70,217) ÷ 2,45,89,506 − number of revolutions × 51″ ÷ 3121.

(ii) Moon's apogee in revs. etc. = (Days × 900 + 22,60,356) ÷ 29,08,789 + number of revolutions got × 10″ ÷ 297.

Example 2. (a) Days from Epoch = 5,28,931: Find the mean Moon. (b) Find the mean Moon for Ujjain mean noon, immediately prior to Epoch, and for Epoch.

(a) By formula (i), the approximate mean Moon = (5,28,931 × 9,00,000 − 6,70,217) ÷ 2,45,89,506

= revs.f 19,359 − 4-11-31.

= The subtractive seconds = 19,359 × 51 ÷ 3,121 = 316.

∴ Exact Mean Moon = *rā*.4-11-31 − 316″ = *rā*.4-11-25-7.

(b) By formula (i), for the said Ujjain mean noon the approx. mean Moon = (0 × 9,00,000 − 6,70,217) ÷ 2,45,89,506

= − *rā*.0-9-48.8 = *rā*.11-20-11.2

Adding the mean motion of apogee for 22 1/3 *nāḍikās*, 4° 54′.3, the mean Moon at epoch = *rā*. 11-25-5.5.

(*Note:* The actual apogee got by modern constants is *rā*. 11-24-47.6, and we see the difference is only 18 minutes.)

2b. A.पक्षावर
A.स्वरत्तनि; B1.2.खरत्रुने; B3.स्वरन्तुने
c. B3.षड्रूनेंद्रिय; B1.3.षद्घनेन्द्रिय; D.षट्व्योमेन्द्रिय

3a. A.B2.गुणितं
b. A.गुणावर्त्तु. B.पक्षात्
c. A.सप्ताष्टास्वर
d. A.नवाश्विक्ले श

4a. B1.2.विषयध्री°; B3.विषयघ्नीं
b. D.त्वृणं
c. A.स्वेच्चे. A.दिघ्नानि; B1.2.C.D.खाकीग्नि;
B2.दिध्रानि
d. A.B.स्वरदस्त्रयमोद्धृते (B.यमोधृते);
C.स्वरनन्दयमो°; D.स्वररन्ध्रयमहृता [नि] विकला:

Example 3. (a) Days 5,28,931. Find the Moon's apogee. (b) Find the Moon's apogee for Ujjain mean noon prior to Epoch, and for Epoch.

(a) By (ii) the approx apogee in revs. = (5,28,531 × 900 + 22,60,356) ÷ 29,08,789

= Revs. 164-5-5-33.1

The additive seconds = 164 × 10 ÷ 297 = 6.

Adding, the exact apogee = *rā.* 5-5-33.2.

(b) For the said Ujjain mean noon, the apogee = (0 × 900 + 22,60,356) ÷ 29,08,789 = *rā.* 9-9-45.

Adding 2′.5, the mean motion of apogee in 22 1/3 *nāḍikās,* the apogee at Epoch = *rā.* 9-9-47.5.

(Note: The actual position was rā. 9-9-34. See how close this is.)

The explanation for the formula relating to the mean Moon is as follows: It was shown under I.14 that in the *Saura yuga* consisting of 6,57,46,575 days there are 24,06,389 revolutions of the Moon. For the sake of convenience, the author has first assumed that in whole numbers there are 9,00,000 revolutions in 2,45,89,506 days, intending to give a correction as a second step. Therefore we get that in 6,57,46,575 days there are 6,57,46,575 × 9,00,000 ÷ 2,45,89,506 revolutions = rev. 24,06,389-0-10-55-27.

Thus we get 10° 55′ 27″ more than what we should get, and this has to be deducted, proportionately to the revolutions got. For one revolution the deduction is, 10° 55′ 27″ /24,06,389 = 39,327″/ 24,06,389. In the place of this fraction the author gives the approximate but simpler fraction 51″/ 3121, since the error caused will be only plus 4″ in the *yuga.*

The manuscript reading, *kharkāgni* if read as *khārkāgni* as done by TS and NP, (= 51″/3120) will cause an error of minus 8″, which also is negligible but unlikely, since the author then would have given the reduced form, 17″/1040. That is why we have read it as *kvarkāgni,* 3121.

The deduction of 6,70,217 is explained in the manner of the Sun's deduction: We have seen that at the end of Śaka 427, the end of 3,606 solar years from the beginning of Kali fell 42/800 days, i.e. *nā.* 3-9, after Ujjain mean midnight after Epoch. Under I.14 it was shown that according to the *Saura* there are 24,06,389 revolutions of the Moon in 180,000 years. Therefore, in 3,606 years the revolutions gone are 48,207.992966. At the beginning of Kali, the Moon, like the Sun, began a revolution, according to the *Saura.* So, .007033 revolution remains to be completed now. We have seen that for 2,45,89,506 fractional parts there is one revolution. So, for .007033 revolution, the parts to go are 2,45,89,506 × .007033 = 1,72,946. These must go after the completion of the solar year to complete the revolution. But the year ends *nā.* 3-9 + *nā.* 30 = *nā.* 33-9 from mean noon. In one day, there are 9,00,000 parts, and for *nā.* 33-9, the parts to go are 9,00,000 × 33.15 ÷ 60 = 4,97,250. Therefore at mean noon the parts to go for completing the revolution are 1,72,946 + 4,97,250 = 6,70,196. Since these have to go, this number is deducted from the total parts got by multiplying the days by 9,00,000. Here, the author gives 6,70,217 arrived at by using approximate work in the place of 6,70,196, for the difference is small, the error caused being only minus one second in the *yuga.*

Now for the explanation of the rule to get the longitude of apogee: We do this using the element given in Āryabhaṭa's *Ārdharātrika* system, or which is the same, in the *Khaṇḍakhādyaka,* since this is not given in I.14, and the original *Saura* is not available. From them we learn that in the *Mahāyuga* of

1,57,79,17,800 days there are 4,88,219 revolutions of the Moon's apogee. If the approximate rule given as the first part is used, we get that there are, 900 × 1,57,79,17,800 ÷ 29,08,789 revolutions = rev. 4,88,218-11-25-26-48 for the *Mahāyuga*. But this is 4° 33′ 12″ less than the correct value, and this latter has got to be added, per Mahāyuga, i.e. for 4,88,219 revolutions. Therefore the addition for the revolutions gone is, revolutions gone × 16,392″ ÷ 4,88,219. In the place of this fraction the author gives 10″/297, as the difference is very small, for by using this the error will be only plus 2" in the *Saura yuga* of 1,80,000 years, which is negligible, especially in the apogee.

If, instead of our (as also NP's) emendation, *svararandhrayama*, we make another emendation *vasurandhrayama* giving the fraction as 10″/298, then it will be very correct. As for our reading *randhra* in the place of the author's *dasra*, it is necessary since otherwise there will be an error of plus one degree and a half in the *Mahāyuga*. That is why TS have given the emendation *svaranandayama* meaning the same as our reading, but *randhra* fits the letters better than *nanda*.

The correctness of the kṣepa is shown hereunder: 3606 years of Kali ended *nā*. 3-9 after Ujjain midnight next to Epoch. The revolutions of apogee for 3606 years = 4,88,219 × 3606 ÷ 43,20,000 = 407.527248611. At the beginning of Kali the longitude of apogee was 0.25 revolutions. Therefore at *nā*. 3-9 after the said Ujjain midnight, the longitude is 0.25 + 0.527248611 = 0.777248611 rev. The fractional parts (at 900 per day), for 0.77248611 rev. = 29,08,789 × 0.777248611 = 22,60,852. This is the *kṣepa* to be added at the end of the year. But Ujjain mean moon, for which we want the apogee, is *nā*. 33-9 earlier, and the parts for this interval = 900 × 33.15 ÷ 60 = 497 has to be deducted. ∴ the *kṣepa* is 22,60,355. The author gives 22,60,356, *which differs by only one unit and causes practically no difference.*

[राहुः]

‘(त्रि)घन(शत)’घ्ने‘नवकैकपक्षरामेन्दुदह(नरस)’सहिते ।
‘(स्वर)यमवसुभूतार्णव-गु(ण)धृति’भ(क्ते) [क्र]माद् राहोः ॥ ५ ॥

चक्रात् पतितं (वक्त्रं) षड्राशियुतं तु पुच्छाख्यम् ।
(नव)तिविवरस्य लिप्ता विक्षेपः सप्त(तिर्द्वि)शति ॥ ६ ॥

Rāhu: Maximum latitūde

5. Multiply the days from Epoch by 2700, add 63,13,219 and divide by 1,83,45,827. Revolutions etc. are obtained, to be used in getting Rāhu.

6. This deducted from twelve *rāśis* is the Rāhu-head (i.e. ascending node of the Moon.) Rāhu-head plus six *rāśis* is the Rāhu-tail (i.e. descending node). At the (maximum) distance of 90° from Rāhu (the node), the Moon's latitude is 270 minutes (i.e., this is the maximum latitude.)

5a. A1.B1.2.द्विघनगजघ्ने (B1.2.°घ्नेन्) C.दशघ्ने. B.घकै-
b. A.दहशाष्दाः; B.दहनशब्दाः; C.दहशब्दाः|; D.दहन षट्-
B.प्रहिते (B2.3.°तेः)
c. A.चरयम; B.वरयम; C.om स्वर; D.करयम
A.वसुधृतार्णव
d. A.गुधृतिभक्तभाद्राहोः; (A2.माद्राहोः) B.गुणा
धृतिभूता साद्राहोः; C. धृतिभिः D.°द्राहुः

6a. A.B1.2.चक्रं
b. A.युतं वसुछाख्यं; D.च for तु
c. A.सहति; B1.अहति; B2.3.ग्रहति
C.सहित; D.तिमिर
d. A.B1.2.सप्तता दिशती

The Head of Rāhu in revolutions etc. = − (Days × 2700 + 63,13,219) ÷ 1,83,45,827.

The tail of Rāhu = the above + 6 *rāśis*.

As for Moon's latitude, for a maximum moon ~Rāhu, equal to 90°, there is the maximum latitude, 270′. For other differences, lat = 270′ sin (Moon ~ Rāhu) ÷ 120, as given in verse 25, which reduces to, lat = 9 sin (Moon ~ Rāhu)/4. This is given by the *Saura*, and followed by all later *Siddhāntas*.

Example 4. Compute Rāhu (a) for Ujjain mean noon prior to Epoch, and (b) for Epoch.

(a) In this case, days from Epoch is zero.

∴ Head of Rāhu in revs. = − (0 × 2700 + 63,13,219) ÷ 1,83,45,827 = − *rā*.4-3-53-3 = *rā*.7-26-6-57.

(b) Since the Epoch is *nā*. 22-20 later, the motion for this interval, rev. 67/180 × 2,700 ÷ 1,83,45,827 = 1′ 11″ has to be deducted.

Rāhu-head according to the *Saura* for the time of Epoch, *viz.* mean sunset at Yavanapura, is *rā*. 7-26-5-46. *Actually it is rā. 7-26-0, and the difference is within 6′*. The calculation of the latitude will be explained in the context of the computation of eclipses.

The rule of Rāhu: Like that for the apogee, this rule must be derived from the constants given in the two works that follow *Saura* since the original *Saura* is lost. In the *Mahāyuga* consisting of 1,57,79,17,800 days, there are 2,32,226 revolutions of Rāhu, (i.e. Moon's nodes). Using the rule for Rāhu here, we get, 2700 × 1,57,79,17,800 ÷ 1,83,45,827 = rev. 2,32,226-0-0-46-2 of Rāhu per *yuga*. This is 46′ 2″ more than what we should get, but neglected by author as being small especially in a *karaṇa* intended to be used for a comparatively short period, considering the fact that even in 10,000 years the error is only 6″, which will not affect the result. That is why the second step of correction is not given, unlike in the case of the mean Moon and apogee. If a correction is wanted here also, multiply the revolutions by 10, divide by 848, and add the resulting seconds to Rāhu. Or, instead of using 1,83,45,827 as divisor use 1,83,45,827.2 *i.e.*, in the rule, take the multiplier to be 27,000, *kṣepa* 6,31,32,190, and the divisor 18,34,58,272.

At the end of 427 Śāka or Kali years 3606, the revolutions to get Rāhu = the longitude at the commencement + the revolutions in 3606 years.

= ½ + 3606 × 2,32,226 ÷ 43,20,000

= 194 + 1,23,913/3,60,000.

Omitting the full revolutions, the parts for the fraction remaining are the *kṣepa*, for the end of 3606 years Kali.

Since there are 1,83,45,827 parts for a revolution, the parts of *kṣepa* = 1,83,45,827 × 1,23,913/3,60,000
= 63,14,684.

Since we want the *kṣepa* for Ujjain mean noon, *nā*. 33-9 earlier, we have to subtract the parts for this time.

Since there are 2700 parts in a day, for *nā*. 33-9 we have *nā*. 33-9 × 2700 ÷ *nā*. 60 = 1492 parts.

∴ the *kṣepa* for mean noon is 63,14,684 − 1492 = 63,13,192.

The author gives 63,13,219, the difference, 27 parts, giving a difference of 2″ in longitude being very small; for by neglecting a small fraction equal 1/7 in the divisor to make it a whole number, can give this difference.

The readings here are extremely corrupt: Our explanation itself will show that the emendations we have made are necessary. We have read *dvighanagaja* as *trighanaśata* while TS give the correction *trighanadaśa.* The textual reading, *carayamavasubhūtārṇavaguṇādhṛtibhakta* is corrected by us as *svarayamavasubhūtārṇavaguṇadhṛti-bhakte.* But TS give the correction *yamavasubhūtārṇavaguṇadhṛtibhiḥ.* Here it is improper on their part to omit two letters *cara* though they require this omission since in *trighanagaja* they have given *daśa* for *gaja*, instead of *śata* given by us. Nothing is gained by reading *daśa* instead of *śata* for *gaja*. Further, by omitting *cara* which is a corruption for *svara*, the number 7 in the unit's place is omitted by them, with the result that in the *yuga* an error of plus 30° and more is caused in Rāhu, while it is actually 46′ 2″ according to our correction. NP make the correct emendation *trighanaśataghne* but emend *cara* to *kara.*

We have corrected *dahanaśabdāḥ* as *dahanarasa* which fits the rule as shown. But TS content themselves with remarking that here the numbers of the *kṣepa* cannot be determined owing to the extreme corruption of the text. NP have made the emendation *dahanaṣaṭ* here, which too will serve the purpose.

That the Head of Rāhu obtained by deducting what is got from 12 *rāśis* has been explained in dealing with the *Pauliśa.* We read *sahati* in the text as *navati,* since the difference of 90° between moon and Rāhu gives the maximum latitude, which is 270′ according to the *Saura,* as also in all later Hindu Siddhāntas like the *Āryabhaṭīya.* Or we may read it as *mahati,* since the greatest difference, *viz.* 90° will give the greatest latitude, *viz.* 270′. But TS read it as *sahita,* and give something farfetched and unacceptable. NP emend *sahati as timira,* which neither accords with the lettering of the manuscript nor give the sense 90° required here. That the latitude is proportionate to the sine of (Moon ~ Rāhu) has already been explained in the context of the *Romaka,* and will also be shown below, in verse 25 of this chapter.

[स्फुटरविचन्द्रौ]

अंशाऽशी(त्या ही)नोऽर्कः केन्द्रं स्वोच्चवर्जीतश्चन्द्रः |
(तज्ज्या)ऽर्कस्य 'मनु'घ्नी 'रूपाऽग्नि'गुणा शशाङ्कस्य || ७ ||
'व्योमरसाऽ नल' भक्ते तच्चा(पं) द्विस्थितं (स्वकेन्द्र)वशात्
प्रथमे चक्रस्यार्धे क्षयश्चय: पश्चिमे भागे || ८ ||
सौर्यं स्थापितचापं तद्भुक्तिघ्नं 'खखा(ष्टि)यम'भक्तम् |
प्रथमवदर्के कार्यं चन्द्रे च दिवाकरवशेन || ९ ||

(True Sun and Moon)

7. The mean longitude of the Sun *minus* 80° is called the Sun's (mean) anomaly. The mean Moon *minus* its apogee is its (mean) anomaly. Multiply the sine of the anomaly of the Sun by 14, and that of the Moon by 31.

8. Divide each by 360, and find their arcs. Put the Sun's arc in two places, for subsequent use. The arc of each is to be deducted from its mean longitude if

its anomaly is less than six *rāśis*, and added if more than six *rāśis*. (The true Sun and Moon at Ujjain mean noon is got.)

9. Multiply the Sun's arc, kept aside in one place, by the Sun's true daily motion, (in minutes), and that kept in the other place by the Moon's true daily motion (in minutes). Divide each by 21,600. Add or subtract the resulting minutes in the respective true longitude found, according as the Sun's arc was first added or subtracted. (The true Sun and Moon at Ujjain true noon is obtained.)

The following are the formulae:

(a) *To get the true Sun:*

(i) Mean Sun $-$ 80° $=$ Sun's anomaly.

(ii) Sine Sun's anomaly $\times$ 14 $\div$ 360 $=$ sin Sun's equation of the centre. Its arc is the equation of the centre. (Eq.C).

(iii) Mean Sun $\mp$ Sun's equation of the centre $=$ true Sun at Ujjain mean noon. (The upper sign, if the anomaly is less than 6 *rāśis,* lower if more.)

(iv) iii $\mp$ Sun's equation of the centre $\times$ Sun's daily motion in minutes $\div$ 21,600 $=$ True Sun at true mean noon. (Addition or subtraction as in iii.)

(b) *To get true Moon:*

(i) Mean Moon $-$ Moon's apogee $=$ Moon's anomaly.

(ii) Sine Moon's anomaly $\times$ 31 $\div$ 360 $=$ sine Moon's equation of the centre. Its arc is the equation of the centre.

(iii) Mean Moon $\mp$ Moon's equation of the centre $=$ true moon, at Ujjain mean noon. (The upper sign, if the Moon's anomaly is less than 6 *rāśis,* lower if more.)

(iv) iii $\mp$ Sun's equation of the centre $\times$ Moon's true daily motion in minutes $\div$ 21,600 $=$ True Moon at true noon. (Addition or subtraction as in (a) iii).

Example 5. Days = 5,28,931. Find the true Sun at true noon, Ujjain.

From example 1 (a) the mean Sun = *rā.* 1-5-15.7. The longitude of Sun's apogee is 80°. From these two:

(a) (i) The Sun's mean anomaly = *rā.* 1-5-15.7 $-$ 80° = *rā.* 10-15-15.7.

(ii) Since anomaly = sine *rā.* 10-15-15.7 = Sin *rā.* 1-14-44.3 = 84′ 27″, ∴ Sine equation of the centre = 84′ 27″ $\times$14 $\div$ 360 = 3′ 17″.

∴ Equation of the centre = arc 3′ 17′ = 1° 34′.1.

(iii) True Sun at mean noon = *rā.* 1-5-15.7 + 1° 34′.1 = *rā.* 1-6-49.8, (addition because the anomaly is greater than 6 *rāśis*).

(iv) True Sun at true noon = *rā.* 1-6-49.8 +1° 34′.1 $\times$ 57.4 $\div$ 21,600 = *rā.* 1-6-49.8 +0′.3 = *rā.* 1-6-50.1. (That the daily motion of the Sun is 57′.4 will be given under verse 13, below.)

7a. A.॰शीत्योद्विनो; B.अशाशत्योद्विनो

b. A.B1.2.केन्द्रक्षः A1.वर्जित; A2.वर्ज्जित; B.चज्जित

c. A.B1.॰तज्यार्कस्य

d. A1.गुणिता; A2.गुणता

8a. B.रयानल A.तच्चाप C.द्विःस्थितं; B.दिस्थित A.B.C.शशाङ्कवशात्; D.शशाङ्करवौ

c. B.om प्रथमे

9b. B.भक्तिम्नं. A.B.खखाब्धि

d. A2.चंद्रेव

Example 6. Find the true Moon at true noon at Ujjain, the Days being 5,28,931.

From example 2 (a), the mean Moon for 5,28,931 days gone is *rā.* 4-11-25.7. From ex. 3 (a) the Moon's apogee for the given days gone is, *rā.* 5-5-33.2. From these,

(b) (i) The Moon's anomaly = *rā.* 4-11-25.7 − *rā.* 5-5-33.2 = *rā.* 11-5-52.5.

(ii) Sine anomaly = sine *rā.* 11-5-52.5 = sine *rā.* 0-24-7.5 = 49′ 2″.

Sine equation of the centre = 49′ 2″ × 31 ÷ 360 = 4′ 13″.3.

Equation of the centre = arc 49′ 2″ = 2° 1′.

(iii) True Moon at mean noon = *rā.* 4-11-25.7 + 2° 1′ = *rā.* 4-13-26.7.

(iv) True Moon at true noon = *rā.* 4-13-26.7 + 1° 34′.1 × 729.1 ÷ 21,600

= *rā.*4-13-26.7 + 3′.2 = *rā.*4-13-29.9 (That the Moon's daily motion is 729′.1 will be seen from example under verse 13 below. The addition is as the Sun's Eq.C.)

It should be noted here that the apogee of the Sun, given as 80° is too far from the correct apogee for the time of the work *viz.* 77° 19′. There is no doubt about the reading here, since the *Ārdharātrika* and the *Khaṇḍakhādyaka* too give 80°. So much error is unbelievable in the *Saura,* and must be explained thus: At first the practice might have been to get the mean longitude of the Sun for the days from the commencement of the true solar year and 80° deducted to get the anomaly, for this would be equivalent to deducting about 77° 50′, (since the Eq.C at this time is about 2° 10′), from the correct mean Sun, not much different from the correct 77° 19′ to be deducted. Later, by some mistake, the deduction of 80° was instructed to be done from the correct mean Sun itself. The apogee for the time computed by the *Modern Sūrya Siddhānta* is 77° 15′.

From the instruction to multiply the sine of the Sun and Moon's anomalies by 14 and 31, respectively, and divide by 360, to get the sine of the respective equation of the centre, we see that this Siddhānta actually uses epicycles like the *Āryabhaṭīya* etc, though not mentioning the word, and we can say that epicycles appear in the Hindu Siddhāntas for the first time in the *Saura,* and the others following using epicycles and excentries. The *Modern Sūrya Siddhānta* gives the same degrees of epicycle for the Sun, but 32° for the Moon instead of 31°. Further, in the *Saura,* the epicycle is uniform, while in many Siddhāntas like the *Āryabhaṭīya* there is difference between the degrees at the ends of odd and even quadrants. For instance, the degree of epicycle mentioned above for the Sun and the Moon in the *Sūrya Siddhānta* is for odd quadrants, being less by 20 minutes at even quadrants.

The computations mentioned above can be simplified, since the multiplier and the divisor are constants and small arcs are proportionate to the sines. Thus, we can get the Sun's Eq.C. in minutes by multiplying its sine anomaly by 1.114. In the example, multiplying 84′ 27″ by 1.114 we get 94′ 6″, the equation of the centre. We can get the Moon's Eq.C. by multiplying its sine anomaly by 2.467, and if the result is in excess of 225 minutes, adding 1/235 of the *excess* to the result. In the example, multiplying 49′ 2″ by 2.467, we get the equation of the centre, 121′ 3″. In the same way, we find the Sun's maximum equation of the centre to be , 120′ × 1.114 = 133′.7. The correct maximum for the period of our author is 119′.5. The large difference is due to the Moon's Annual Equation being wrongly applied to the Sun with its sign changed, in Hindu astronomy, as already alluded to, since by doing so the *tithi* is not affected, the constants having been derived by the analysis of the syzygies, which are, in essence, ends of particular *tithis.* Adding the maximum Annual equation to the correct equation of the centre of the period, we have 131′.5. See how close this is to the value, 133.7 of the *Saura,* and how far from the 140′ of the *Pauliśa,* and the 143′ of the *Romaka* and of Ptolemy.

In the same way, the maximum of the Moon's equation of the centre is $120' \times 2.467 + (120' \times 2.467 - 250) \div 235 = 296' + .3' = 296'.3$. This too was determined by analysis of syzygies at the occurrence of eclipses. According to modern astronomy, the mean of the maximum equation of the centre of the Moon at true syzygies is 297'.3, a difference of only one minute! (At mean syzygies it is 303'.5).

Epicyclic theory

We shall now proceed to explain the epicyclic theory of planetary motion, used by this *Siddhānta*, and show how it works, by relating it to the modern theory, which latter is as follows: The earth and the other planets like Mercury etc. move round the Sun in eclipses, with the Sun at one of the two foci. The point nearest to the Sun on the ellipse is the perihelion, and the most distant, aphelion, which, from the point of view of the earth, are called the perigee and apogee, respectively. In the same manner, the Moon moves in an eclipse round the earth at one focus. This fact relating to the planets was first discovered by the European astronomer Kepler and is called *Kepler's First Law* of planetary motion. The line joining the Sun and the planet (or the earth and the Moon), called the radius vector, sweeps equal areas in equal time. This is *Kepler's Second Law* of planetary motion. From this it can be readily inferred that the motion of the planet is swiftest at perihelion (or perigee for the Moon) and lowest at aphelion. *Kepler's Third Law*, that the square of the periodic time of the planets round the Sun is proportionate to the cube of the distance, is not wanted for our purpose here. The celebrated astronomer, Newton, showed that all the three laws follow from his *Theory of Universal Gravitation*, that all bodies attract one another with a force proportionate to their masses, and inversely proportionate to the square of the distance between them.

But ancient Indian astronomers held the view that the earth is the centre round which the Moon, Sun and planets move. All the motion is in circles, and uniform. To explain the non-uniformity of the apparent motion caused by the equation of the centre, it was assumed that these bodies moved in circles called epicycles, (*manda-vṛttas*), the centres of which moved in circles round the earth as centre. In the case of the star-planets, another set of epicycles called epicycles of conjunction or *śīghra-vṛttas* were assumed, the effect of which is to convert helio-centric positions into geocentric. As the observers are on the earth, it is geocentric positions that are wanted, and therefore given, whether by Hindu astronomy or by modern western astronomy. The inaccuracy in the positions given by the former is due to unawareness of the elliptic motion and the inability to observe accurately for want of adequate instruments, with the result that small errors in the constants accumulated in course or time, to give large errors.

It has been said that whether the heliocentric theory is adopted or the geocentric theory, the result in so far as this goes, is the same. Then, it may be asked, is it not better to adopt the geocentric theory which agrees with our perception? No. There is a clinching proof for the motion of the earth round the Sun, in the phenomenon of *aberration* which makes the Sun and star planets appear to be a little in advance of their real positions, the quantity being so small that very accurate measurement is required to find it, capable only by modern instruments. The heliocentric theory is also simpler, and satisfies the requirement of least assumption.

Adhering to only circular motion, so satisfying to their minds, the ancients had to get the equation of the centre, caused by the motion on the ellipse. They sought to achieve it in two ways, by using epicycles, as indicated already, or excentric circles, or both. How the ex-centric is used for the purpose is explained as follows:

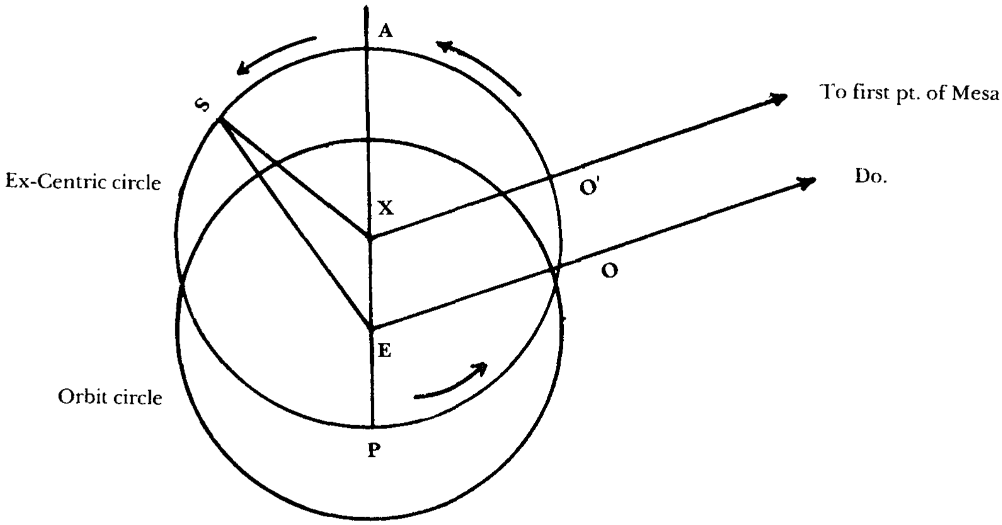


Fig. IX. 1-a.

The earth E, is the centre of the Orbit-circle, of 'radius' equal to the sine of Three *rāśis* (120′ in this work). O indicates the first point of Meṣa, in the direction EO. EA is the direction of apogee, A, O EA being the longitude of apogee (P is the perigee). X is the centre of the ex-centric circle on which the Sun, Moon or star-planets move uniformly according to the mean motion. X is on EA, at a distance, towards A, equal to the sine of the maxi-minimum Eq. C. S is the position of the body, angle SXO′ being the mean longitude of the body. XO′ also is directed to the first point of Mesha. EO and XO being practically parallel. ASX = mean longitude − longitude of apogee = mean anomaly.

SEO is the true longitude, which has got to be found. Since XO′ and EO are parallel, SEO = SXO′ − XSE, where XSE is the Eq. C. Since XSE changes sign on the right hand side of PA, SEO = SXO′ +XSE on that side. Thus we have that in the first case, when the body is from apogee to perigee, *i.e.* when the anomaly is less than six *rāśis,* the equation of the centre is subtractive. In the second case, where the mean anomaly is more than six *rāśis,* is it additive.

Next, for the equation of the centre. If the maximum Eq.C, represented by EX, is small, as in general, then taking SE and SX to be practically equal, sine Eq. C = sine XSE = XE. sine SXE ÷ SE
= XE. sine SXA ÷ SX
= max Eq.C × sine mean anomaly ÷ 120′ (120′ being the radius).

In this computation, the astronomers belonging to the school of Āryabhaṭa find the Eq.C using the actual radius vector, SE, in accordance with the geometric representation. But Bhāskaracārya in his *Siddhānta Śiromaṇi* does not use it, and gives reasons for not using it. Now, if degrees of epicycle are given, as in this *Siddhānta*, instead of sine maximum Eq. C, these degrees are multiplied by 120′ and divided by 360° to get sine maximum Eq. C. (i.e. EX). Therefore, sine Eq. C = (degrees of epicycle × 120′ ÷ 360°) × sine anomaly ÷ 120′

= degrees of epicycle × sine anomaly ÷ 360°, as in the text.

We shall now see how the use of the epicycle gives the Eq.C.

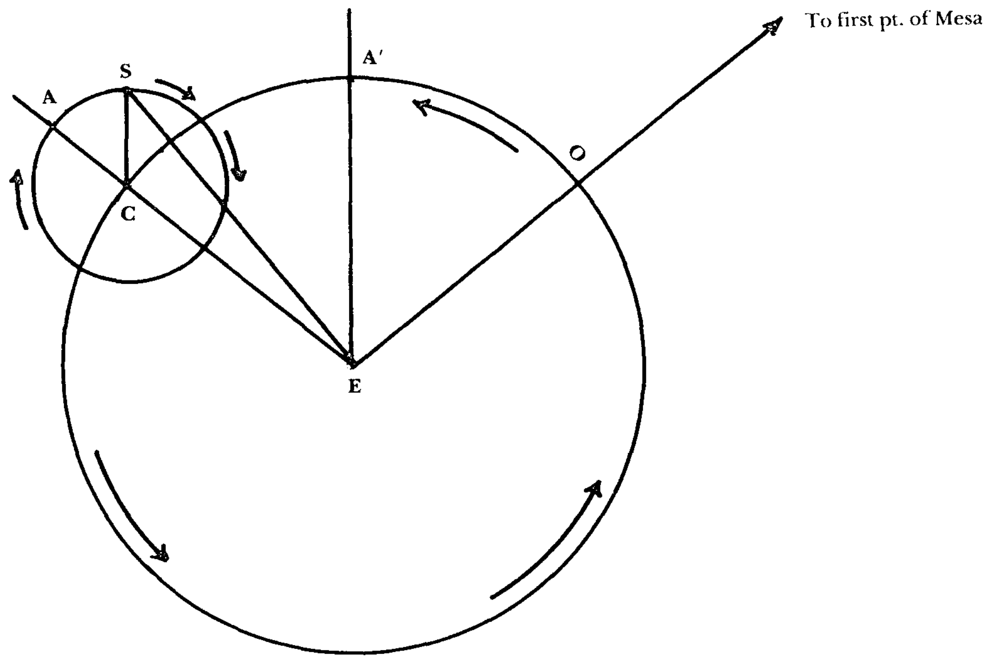


Fig. IX. 1-b.

Here too, E, the centre of the earth is the centre of the orbit circle of radius 120'. On the orbit circle, the centre C of the epicycle on which the body S is situated, moves according to the mean motion of the body. The radius of the epicycle is the degrees of epicycle given in the text × 120' ÷ 360°, which is the maximum Eq.C, as already seen. At the two points of intersection of the epicycle with the line of apogee, EA, arc A the apogee, and P the perigee. The body moves on the circumference of the epicycle, with its mean motion in the direction opposite to the motion of C. Angle ACS is the anomaly.

Now, draw EA' parallel to CS. Then angle AEA' also is the anomaly. Since CEO is the mean body, A'EO is equal to the longitude of apogee. Since SEO is the true longitude and CEO is the mean longitude, angle CES is the Eq.C. Therefore, mean longitude *minus* Eq.C. = true long, (the anomaly being less than 6 *rāśis* in the figure. If the anomaly is more than 6 *rāśis*, S is greater than P, and the Eq. C. becomes additive). The Eq. C. is got in the same way as in the excentric method.

We have now to show that in either of the methods, the Eq. C. is the same, i.e. angle XSE in fig 1a = angle CES in fig 1b. In the two triangles XSE and CES in the respective figures, it has been

said that EX is equal to CS. XS is equal to CE, both being equal to 120′. Angles SXE and SCE are also equal, since they are 180° *minus* the equal mean anomalies, SXA and SCA. Therefore, the two triangles are congruent, and so angles XSE and CES are equal, as required to be shown. In the matter of the correctness of the degrees of epicycle we have to take the authority of the work. That it agrees with the *Original Saura* can be seen, the same being found also in the *Ārdharātrika system* and *Khaṇḍakhādyaka.*

Bhujāntara correction

We shall now show why the correction called *Bhujāntara* is done. The Days used in the formulae are mean solar days. (That is why the mean longitudes are taken to be proportional to them.) Therefore the true longitudes got are for mean noon. But we want the longitudes for true noon. So we have to apply a correction which is the motion during the interval between mean and true noons. If the Sun's Eq.C. is positive it is east of its mean position, and reaches the meridian later than mean noon by a certain number of *prāṇas* (*prāṇa* = 4 seconds of time, one sixth of a *vināḍī*) equal to the number of minutes of arc. Being later, the Sun and Moon's motion during the interval has to be added. If the Eq.C. is negative, then the true Sun is west of its mean position and true moon is earlier. Therefore the motion is to be subtracted. The motion in the interval is found by the proportion: (Since there are 21600 prāṇas in a day) 21600: daily motion :: Minutes of Sun's equation of the centre: motion during the interval. From this it can be seen that this correction has got to be done not only to the Sun, but also to the Moon and the star-planets as well.

Udayāntara correction

We must add that this correction for equation of the centre is not sufficient. Another correction has got to be made for what is called *Udayāntara* or reduction to the equator, *i.e.* reducing the motion on the ecliptic to motion on the celestial equator which is the circle on which time has to be measured. Both these corrections form the equation of time, being the interval between true and mean noons. But Hindu astronomers prior Śrīpati were unaware of this correction.

[देशान्तरसंस्कारः]

पञ्चाशता त्रिभिस् त्र्यंशसंयुतैर्योजनैश्च नाड्येका |
समपूर्वपश्चिमस्थैर्नित्यं शोध्या च देया च || १० ||

Deśāntara correction

10. One *nāḍi* for every 53 1/3 *yojanas* has to be deducted or added (to Ujjain noon) by people in places east and west, respectively, of the Ujjain meridian, (to get their own noon.)

Ujjain was the Greenwich of the Hindus, and the line of longitude passing through Laṅkā, Ujjain and the North pole was taken as the prime longitude. It is well-known that noon occurs earlier and earlier as the longitude of a place is more and more east, and *vice versa.* The author says that for every 53 1/3 *yojanas* of distance east or west, there is one *nāḍi* earlier or later. The idea is that therefore the daily motion of the body should be multiplied by the *nāḍis* got, divided by 60, and the resulting minutes of arc should be subtracted or added to the true longitude, according as the place is east or west, to get the longitude for local noon.

10a. A. पञ्चांशताः

Example 7. Days, 52931. Benaras is east of Ujjain longitude by 68 yojanas. Find the true Moon at noon at that place.

From example 6, the true Moon at Ujjain noon is *rā*.4-13-29.9. The difference in time for Benaras = *nāḍikās* (68 ÷ 53 1/3), earlier. From this, the correction for local noon = 729′.1 × 68 ÷ (53 1/3 × 60) = 15′.5, **subtractive**. (The Moon's daily motion for the day will be shown to be 729′.1 under verse 13.)

∴ The true Moon required = *rā*.4-13-29.9 − 15′.5 = *rā*.4-13-14.4.

The instruction is explained thus: The author takes it that for the region of Ujjain the length of the latitude circle is 3200 *yojanas.* The Sun, in its apparent diurnal motion westward goes once round the circle in 60 *nāḍikās,* crossing all the meridians on the earth. There are thus 3200 ÷ 60 = 53 1/3 *yojanas* for one *nāḍi,* and a place east by this distance has its meridian crossed by the Sun, *i.e.* its noon earlier by one *nāḍi,* and west, later. The motion for this time is calculated by the proportion, 60 *nāḍis:* daily motion :: the *nāḍis* got: the motion for the same. That the motion is deductive if the noon is earlier, and *vice versa* is plain. (This is for direct motion, the Sun and the Moon alone being considered here. If the daily motion is retrograde, as is possible in the case of the star-planets, it is obvious that the subtraction and addition have to be reversed.)

But it is to be noted that in the *Ārdharātrika* of Āryabhaṭa and in the *Khaṇḍakhādyaka,* the diameter of the earth is given as 1600 *yojanas* from which the equatorial circumference got is 5027 *yojanas.* Therefore the *Original Saura* must have given the same values. The *Modern Sūrya Siddhānta,* and the *Siddhāntas* that follow it also give the same. From this the latitude circle at or near Ujjain should be given according to them as 5027 cos 24° = 4600 *yojanas.* According to the *Āryabhaṭīya,* which uses a *yojana* measure one and a half times that of *Saura* etc., the equatorial circumference would be 3300 *yojanas.* From this, it is 14° latitude circle that would be 3200 *yojanas,* and not Ujjain latitude circle. Why should the author use the *yojana* measure of the *Āryabhaṭīya* instead of that of the *Saura,* and in that why should he use the *yojanas* of the 14° latitude circle instead of the Ujjain (24°) latitude circle seems inexplicable.

[रविशशिनोर्मध्यभुक्तिः]

नव(तिः) सप्तशतीन्दोः सचतुस्त्रिंशद्विलिप्तिका भुक्तिः |
षष्टिर्व्येका विकलाऽष्टकं च मध्या सहस्रांशोः || ११ ||

Mean motion of the Sun and the Moon

11. The mean daily motion of the Moon is 790′ 34″, and that of the Sun is 59′ 8″.

These can be derived from the mean motions of the Sun and the Moon given in the first and second verses. In the former it is said that in 2,92,207 days there are 800 revolutions of the Sun. ∴ 800 revolutions ÷ 2,92,207 = 59′ 8″, the motion for one day. In the latter, we have that there are 9,00,000 revolutions of the Moon in 2,45,89,506 days. ∴ the motion per day = 9,00,000 revolutions ÷ 2,45,89,506 = 790′ 34″. The correction in verse 4 is too small per day to consider.

11a. A.B.नव (A.नच) सप्तसतींदोः
b. B.त्रिशद्विलिप्तिकासु भुक्तिः
d. B.मध्याग्रहस्रांशोः

[चन्द्रकेन्द्रभुक्तिः]

सप्तकला विश्र्यंशाश्चन्द्रोच्चस्येन्दुभुक्तिरनयोना |
केन्द्रस्य परिज्ञेया स्फुटभुक्तिश्चा(न)या कार्या || १२ ||

Motion of Moon's anomaly

12. The daily motion of the Moon's apogee is 6 2/3 minutes. The Moon's mean daily motion less the motion of the apogee is the daily motion of the Moon's (mean) anomaly. The true daily motion is to be found using this motion of anomaly.

We get that the daily motion of the Moon's anomaly is 790′ 34″ − 6′ 40″ = 783′54″. The Sun's mean daily motion itself is the motion of its anomaly, since its apogee has no motion according to this *Saura*, as we have already said. Even if motion is taken into account, it is so small that it is practically nothing per day.

The rule to get the daily motion of Moon's anomaly is explained thus: From verse 3 above, we see that there are 900 revolutions of Moon's apogee in 29,08,789 days. ∴ in one day, the motion is 900 revolutions ÷ 29,08,789 = 6′ 41″. The correction per day is practically nothing and so left out. The author gives it as 6′ 40″, for convenience of expression, since the 1′ left out will not affect the result materially. Since anomaly is mean longitude *minus* longitude of apogee, the motion of anomaly is mean motion *minus* motion of apogee, for it is the daily motions that add up to form the longitude.

[रविशशिनोः स्फुटभुक्तिः]

केन्द्रान्तरज्या गुणिता 'तिथिवर्गे'णोद्धृता च परिणा(म्या) |
तत्कार्मुकं क्षयचयौ भुक्तौ मृगकर्कटाद्येषु || १३ ||
तत्कालभुक्ति(रेषा)ऽऽहोरात्रिकी शशिविशेषात् |
व्यासार्धहता भुक्तिः स्फुटभुक्तिहता स्फुटः कर्णः || १४ ||

True motion of Sun and Moon

13. The daily motion of anomaly should be multiplied by the current sine-interval and divided by 225. This should be reduced to the epicycle, i.e. multiplied by the degrees of epicycle and divided by 360°. The change in sine Eq.C, is got. Its arc should be subtracted from the mean daily motion, if the anomaly falls within *rāśis* 9 to 3, and added if it falls within *rāśis* 3 to 9.

14. This is the true motion per day, for the moment (for which the anomaly is taken.) The true daily motion in the case of the Moon is got by subtracting

12a. B.विचित्र्यंशा
b. A.रतयोना
d. B.स्फुटभक्तिश्चात् या; A. श्चातया

13a. C.केन्द्रज्यान्तरगुणिताः; D.०ज्यागुणिता
b. B. वर्ग्रेणोधृता A. परिणाम्यः; B.C.D. परिणाम्य
d. B1.3. भुक्तो मृगकर्कराद्येषु

the previous day's true Moon from the given day's true moon. The daily mean motion, multiplied by 120′ and divided by the momentary motion per day is the radius vector at the moment.

The following is given here:-

(A) (i) The daily change in sine Eq.C. for short interval = the interval in the tabular sine of anomaly current × daily motion of mean anomaly × degrees of epicycle ÷ (225 × 360).

(ii) The daily change in Eq.C. in minutes of arc = (i) × 3438 ÷ 120. (since the sine is small and there is no difference between sine and arc).

It should be noted here that it is possible to simplify the above work, because the daily anomaly and the degrees of epicycle are fixed for each body, and the rest are constants. Only the interval in the tabular sine of anomaly current varies. For instance, the Moon's daily motion of anomaly is 783′.9, and epicycle 31°. Therefore, the daily change in Eq.C. in minutes of arc

= *the interval in the tabular sine of anomaly current* × 783.9 × 31 × 3438 ÷ (225 × 360 × 120)
= described interval × 8.6.

For the Sun it is, interval in the tabular sine of anomaly current × 59.1 × 14 × 3438 ÷ (225 × 360 × 120) = interval etc × .29.

(ii) The daily rate of true motion for the moment = mean daily motion ± (ii) (additive if anomaly is from *rāśis* 3 to 9 and subtractive if from 9 to 3.)

(B) The true daily motion = the given day's true longitude − the previous day's true longitude.

(C) The radius vector at the moment = 120 × mean daily motion ÷ the daily rate of true motion for the moment.

The sine interval of anomaly used in computing the true Moon or Sun for noon can easily be used to find the daily rate for the noon in question. It is this that should be used for finding the motion during the interval between mean and true noons, as we have done already, and in correcting for longitude. In eclipses also this true daily rate with radius vector, for the moment of syzygies should be used, because this will give the circumstances accurately. This seems to be the author's idea in giving these here. As for the Sun, there is no distinction either in the rate or radius vector between those for the day or for the moment. This is indicated by making the distinction in the case of the Moon alone, using the expression *śaśiviśeṣāt.*

Example 8. For the Ujjain true noon of examples 5 and 6, find the true motion (a) for the Moon (b) for the Sun.

(a) In example 6, the *Bhuja, i.e.* sin of Moon's anomaly got is *rā.*0-24-7.5. Sines being given for every 3 3/4 degrees, the current sine interval is the seventh, equal to 7′ 9″.

∴ By (A ii), the daily change in Eq.C. = 7′ 9″ × 8.6 = 61′.5

By (A iii), the true motion for the said noon = 790′.6 − 61′.5 = 729′.1, (subtraction since anomaly is between *rā.* 9 to 3).

14a-b. A.B.C.D.ज्ञेयाहो
b. A.B2. र्भद्रकी; B1.2. र्भङ्की; C.D.रात्रिकी   d. B1.2.भक्ति A.B1.2हृता:; B3.ऋता:

(b) The *Bhuja* or Sun's anomaly in example 5 is *rā.* 1-14-44.3. The current interval, 12th, is 5′ 44″.

∴ by (A ii), the daily change in Eq.C. = 5′ 44″ × .29 = 1′ .7. By (A iii), the true motion = 59′.1 − 1′.7 = 57′.4, (subtraction since anomaly is between *rā.* 9 and 3).

Example 9. For the noon of example 8, find the Moon's radius vector.

By (C), the radius vector required = 120′ × 790′.6 ÷ 729′.1 = 130′.1.

The following is the explanation of the rules: The true motion during any interval between two moments is the difference between the true longitudes of the moments. The shorter this interval, the more accurate is the motion. In the rule, all factors excepting the sine of anomaly are constants. Therefore the accuracy of the motion depends on the sine of anomaly only. In the case of the Moon, the motion of the anomaly being rapid, there is significant difference in the sine from time to time even within the day, for four or even five sine intervals pass in a day, with the result that the motion is got differently for different times. So the motion has got to be found for shorter periods like the *yāma* in the day, and this is the motion for the time being. For every 225′ of anomaly there is one sine interval. So, during the time for which the anomaly interval is current, the change in sine Eq.C. is caused by the corresponding sine interval current. Therefore, the change in sine Eq.C. is got by multiplying the current sine interval by the degrees of epicycle, and dividing by 360, for the period covered by the corresponding anomaly interval of 225′. From the change in sine Eq.C. the change in Eq.C. is got in minutes (by multiplying by 3438 and dividing by 120, as we have done). This change is for the time to which the current 225′ interval of anomaly corresponds. It is converted into the change per day by multiplying by the daily motion of anomaly in minutes and dividing by 225. This is applied to the mean daily motion to get the daily rate.

Now, we know that the Eq.C. is zero when the anomaly is zero, that it is negative and increases numerically in the first quadrant of anomaly, *i.e.* upto 3 *rāśis,* then decreases numerically, still being negative, to the end of the second quadrant, *i.e.* upto 6 *rāśis* where the value becomes zero again, then in the third quadrant it is positive and increases to a maximum at 9 *rāśis* and then decreases in the fourth quadrant to zero at the end of 12 *rāśis* or zero. From this it can be seen that the Eq.C. goes on decreasing as the anomaly passes from 9 *rāśis* to 3 *rāśis i.e.* the change is negative or subtractive, and goes on increasing as the anomaly passes from 3 *rāśis* to 9 *rāśis, i.e.* the change is positive or additive, as instructed by the text. No harm will ensue from the instruction to multiply and divide the sine interval first and then reduce it to the epicycle, since the sine is small. It is to be noted well that the motion per day found is not actually the motion in the day, but only the rate during the short interval or moment taken in the day. That is why the motion for the day is given by a separate rule, for the Moon. In the case of the Sun there is no distinction between the two, since the daily motion of the anomaly is small. The rule for the radius vector has been explained already when dealing with the *Romaka.*

[रविचन्द्रकक्षे]

'मुनिकृतगुणेन्द्रिय'घ्नः स्फुटकर्णः 'खकृत'भाजितोऽर्कस्य ।
'(स्वरवसु) मुनीन्द्रविषया' भानोः 'खकृतर्तु[व]सुगुणाः' शशिनः ।

Kakṣā of the Sun and the Moon

15. The Sun's radius vector multiplied by 5347 and divided by 40 is called its *kakṣā*. The Moon's radius vector multiplied by 10 is its *kakṣā*.

It is to be noted that the *kakṣa* ŏbtained here, depending as it does on the radius vector is also for the moment taken and its neighbourhood. We can also derive it directly from the daily rate of motion obtained from verses 3-14, above. Thus:

(a) *The Sun's kakṣā* = Sun'sı radius vector × 5347/40 = (120 × 59.13 ÷ Sun's daily rate of motion) × 5347/40 = 9,48,558 ÷ Sun's daily rate of motion.

(b) The Moon's *kakṣā* = Moon's radius vector × 10 = (120 × 790.56 ÷ Moon's daily rate of motion) × 10 = 9,48,680 ÷ Moon's daily rate of motion.

Example 10. Pudukkottai (Lat.10° 24'), on a particular day, new moon falls at nā.20-40 after sunrise. At that moment, the longitude of the sun = the longitude of the Moon = rā.2-0-0. The Rāhu-head, at that time is rā. 7-29-24. The Sun's rate of motion for the time is 57' per day and the Moon's 810'. The daytime is nā. 31-20. Compute the solar eclipse occurring.

For this, the *kakṣā* is found first:
(a) The Sun's *Kakṣā* for the time = 9,48,558 ÷ 57 = 16,641
(b) The Moon's for the time = 9,48,680 ÷ 810 = 1171.2

The author does not use the word *kakṣā* here in its usual sense of orbit, but for the actual distance reduced by some factor, for the orbit is constant, while what we get here is a quantity varying with the rate of motion. Since only the proportion of the distances of the Sun and the Moon from the earth is significant, the reduction will not cause any error. That is why, the word *yojana* giving the measure of distance, is not used here.

Now, the mean *kakṣā*, derived from the mean radius vector, *120'*, is for the Sun, 120 × 5347 ÷ 40 = 16,041. For the Moon it is 120 × 10 = 1200. These obviously are the respective reduced mean distances from the earth. In the *Original Saura* the Sun's orbit is given as 6,89,358 *yojanas,* and the Moon's 51,566 *yojanas,* as we learn from the *Ārdharātrika* system etc. Since the mean distances are proportionate to the orbits etc, if the Moon's orbit, 51,566, is reduced to 1200 as here, the Sun's orbit, by the same factor, must be reduced to, 6,89,358 × 1200 ÷ 51566 = 16,042. This agrees very closely with 16,041 got above. The difference of one may be due to giving the multiplier correct to the nearest whole number, as 5347. Further, the orbits, which is the same for our present purpose as saying distances, are inversely proportionate to the *yuga* cycles given in the Śāstras. Therefore, from the Saura cycles of Sun and Moon in I.14, by the proportion 1,80,000:24,06,389 :: 1200: *x*, we get 16,042 for *x*, the Sun's reduced mean distance, when the Moon's is 1200.

This agreement is the justification for our correcting the reading *drighna* into *digghna.* But TS correct it into *gnighna.* Also, they correct *khar* into *khārka* though there is the alternate reading *khakṛta* fitting correctly in the rule and adopted by us. By their corrections the Sun's mean *kakṣā* will be 5347 and the Moon's 360. Thus the Sun's *kakṣā* becomes, 5347/360 (= 14.85) times the

15a. A.स्पुट
B3. Has an unnecessary gap after कर्णः; B1.2. do not have it.

b. A. खत्रकृभाजितो; C. खार्कभाजितो

c. B.कक्ष्येति. A.करणों; B.कर्णै

d. A.B.द्रिघ्नः; C.ग्निघ्नः

Moon's, against the fact that it is only 13.37 times from the Śāstras, and what they give is equal to saying that there are 14.85 revolutions of the Moon in the year for the *kakṣās* vary directly as the periods of revolution, i.e. inversely as the number of cycles in a given period. We shall also see what havoc their wrong corrections play in the angular diameters following.

[बिम्बमानम्]

'(स्वरवसु) मुनीन्द्रविषया' भानोः 'खकृतर्तु[व]सुगुणाः' शशिनः |
तात्कालिकमानार्थं स्फुटकक्षाभ्यां पृथग्विभजेत् || १६ ||

Measure of the orbs

16. Divide 5,14,787 by the Sun's *kakṣā,* and 38,640 by the Moon's to get the respective angular diameters in minutes at the time.

It is to be noted that the angular diameters (of the orbs of the Sun and Moon) are always given in minutes by our Śāstras. Thus,

(a) The Sun's angular diameter in minutes = 5,14,787/Sun's *kakṣā.*
(b) The Moon's angular diameter in minutes = 38,640/Moon's *kakṣā.*

Example 11. To continue the problem of example 10, find the angular diameters of the Sun and Moon for the time given.

(a) The Sun's angular diameter = 5,14,787′ ÷ 16,641 = 31′.0.
(b) The Moon's angular diameter = 38,640′ ÷ 1171.2 = 33′.0.

The derivation of the rules for the angular diameters is as explained below. The angle formed at the eye by the diameter of the orbs of the Sun and the Moon is their angular diameter and given in minutes. We all know from experience that the nearer the orbs, *i.e.* the lesser the radius vector (given in *yojanas*), the greater is the angle, and the farther away is the orb, i.e. the greater the radius vector, the lesser is the angle. Thus the angle and the radius vector are in inverse ratio, as also the *kakṣā* which is directly proportionate to the radius vector. So we have:

Sine angle at the eye = 120 × diameter in *yojanas* ÷ the radius vector in *yojanas.*

The angular diameter in minutes = 3438 × 120 × diameter in *yojanas* ÷ (radius vector in *yojanas* × 120.)

Here, the author has reduced the diameter in *yojanas* by the same factor used in verse 15 to reduce the radius vector in *yojanas* to the *kakṣā,* and multiplying by 3438, as explained already, to convert the sine into minutes, he has given 5,14,787 for the Sun, and 38,640 for the Moon. The mean *kakṣā* of the Sun derived by us in the explanations is 16,042. Dividing 5,14,787 by 16,042, we have the Sun's mean angular diameter, 32′.1, and the Moon's is 38,640 ÷ 1200 = 32′.2.

16a. A.B1.2.खखवसुश्वमु°; C.D.खवसुखमुनीन्द्र; (D.मुनीन्दु)
b. B.खततर्त्तु°; A.B.C. om व; C.सुरगणाः
c. B2.तत्कालिक; B1.2.तत्कालिका
B2. Unnecessary gap after of शशिनः

The angular diameters derived from the *Original Saura* (and the modern *Sūrya Siddhānta*) are 32′.3 and 32′.0, respectively. Though the difference is small, we must investigate why there is a difference at all. The error is about 160th part of itself in each case. Either the author has taken values slightly different from those of the *Original* to derive the numbers here, or there are some errors in the readings here.

Now for the readings. The first foot of the verse is in excess by one *mātrā*. There are eight digits in the number, *khakhavasu-khamunīndraviṣayāḥ,* though there should be only six digits. So we have corrected *khakhavasukha* into *svaravasu* following the form of the letters also. TS correct it as *khavasukha* etc., giving seven places in the number, as 5147080. By this, the dividend has become ten times what it actually is. Since they give the divisor, viz. the Sun's *kakṣā,* as one third of the actual, (as seen already), they have made the angular diameter in minutes, thirty times the actual. Unaware of the mistakes they have made they wonder why the angular diameter comes thirty times the actual, and make the following curious comment: The correct angular diameters can be got only by dividing what we get here by 30. But the author does not say anything about dividing by thirty. Perhaps in his days there was the well-known understanding that what is got is to be divided by 30 to get the angular diameter. That is why, we surmise, the author has not instructed the division by 30 !! (vide page 50 of the Sanskrit commentary.) All this is the result of the errors in their correction of the readings. NP too have sensed the error here and emend the expressions as *khavasukha munīnduviṣayāḥ* (5,17,080), with the result that "the radius of the Sun is about four times the radius of the earth, the radius of the Moon about one third" (pt. II, p.73).

In the same way, there is one *mātrā* less in the second foot. Therefore, supplying the lost letter we have read *khakṛtartusugaṇāḥ* as *khakṛtartuvasuguṇāḥ*. NP too, do the same. By this we get the five places required in the dividend. But TS read it as *khakṛtartusuraguṇāḥ,* thus making the dividend nine times what it is. They have already made the divisor, the moon's *kakṣa,* three tenths of what the author has said it is. By this the angular diameter of the Moon also has been made thirty times the real value, by them, again rousing their wonder in the manner mentioned before.

[मध्यज्या]

मध्यार्कलम्बिततिथेरन[क्ष]राश्युद्गमैः प्रतीपांशाः |
प्राक् समलिप्ताहानिः क्रमेण पश्चाद्धनं कार्यम् || १७ ||

तन्मध्यविलग्नाख्यं तस्माच्चापक्रमांशकाः क्रमशः |
तैरक्षवियुतयुक्तैर्या ज्या (म)ध्याभिधाना सा || १८ ||

Sin Zenith Distance of Meridian pt.

17. Find the interval between midday and the moment of new moon. If the Sun is east of the meridian (i.e. if new moon falls in the forenoon), find the degrees of right ascension corresponding to this time using the ascensional differences of zero latitude, (*laṅkodayamāna.),* backwards from the Sun. Subtract these degrees from the Sun (= Moon) of the moment of new moon. If the Sun is west of the meridian, (i.e. if new moon is in the afternoon), find the degrees corresponding to the interval counting forward from the Sun, and add to Sun (= Moon).

18. The meridian point of the ecliptic (*madhyalagnam*) is got. Find its declination, north or south. If north, find the difference between the declination and the latitude of the place. If south, add them. The sine of the result is called *madhyajyā, i.e.* sin zenith distance of the point.

The *madhyajyā* is got thus:

(i) Interval between noon and new moon = time of noon ~ time of new moon.

(ii) The degrees of rise of the ecliptic, backward or forward from the Sun, using the corresponding ascensional differences of zero latitude, for the interval in (i) in the forenoon or afternoon respectively is to be found.

(iii) (Longitude of) meridian ecliptic point = The Sun (or Moon) at new moon $\mp$ (ii), (− for forenoon, + for afternoon).

(iv) The declination north or south of (iii) is to be found.

(v) Sine zenith distance of m.e.p. in (iii) = sine (declination found in (iv) $\pm$ latitude), (+ if the declination is south, and the sine found is directed south, ~ if the declination is north, and the sine is directed north or south according as the declination or the latitude is greater.)

Example 12. To continue example 10 using the times given there.

(i) Interval between noon and new moon = *nā.*20-40 − *nā.*15-40 = 5 *nā.*, afternoon.

(ii) Given, Sun = Moon = *rā.*2-0-0, at new moon. Forward counting is to be done (because afternoon) from the first point of *Gemini* where the Sun is. For successive 10° of rise, the times taken are, in *vināḍis,* 105.4, 107.6, 108.8, 108.8. For the interval, of 300 *vināḍis* = 105.4 + 107.6 + 87, there are 10° + 10° + 8° (= 10° × 87 ÷ 108.8) = 28°.

(iii) Adding, the meridian ecliptic point = *rā.*2-0-0 + 28° = *rā.*2-28-0.

(iv) The declination of m.e.p. is 23° 58′N.

(v) Sine zenith distance of m.e.p. = sine (23° 58′ − 10° 24′) = sine 13° 34′ = 28′ 9″, north (∵ declination is greater).

It has been stated by us, above, in the context of the computation of the solar eclipse according to the *Pauliśa,* that in order to get the parallaxes in longitude and latitude, the nonagesimal and the sine and cosine of its zenith distance, (i.e. *dṛgjyā* and *Śaṅku*), are to be found. In the *Saura*, a different method is given to get the sine of the zenith distance of the nonagesimal (z.d.n.) for which the m.e.p. and the sine of its zenith distance are necessary, and given here.

It has been said that the m.e.p. is the point of intersection of the meridian (NZS in the fig.) and the ecliptic (O*r*O′ in fig.) as M in fig. *s* is the position of the Sun at new moon, (occurring in the

17a. D. मध्याह्नलम्बित. B. लम्बिततीर्थे
b. A. °रनराश्यु°; B1.2. °रतराश्यु°; B3. °रसत्तराश्यु°; C. °निरक्षराश्यु; D. °रन्त[र]राश्यु. B. प्रीतिपाशाः
d. A.B. पश्चाधनकार्यः; A2. पश्चाधनकाकैर्यः

18b. B1.3. तस्माच्च
c. B1.3. विपुत
d. A. या ज्याकृतिं सद्याभि°; B1.2. या ज्या सधाभि°; B3. या ज्या सद्धाभि°;

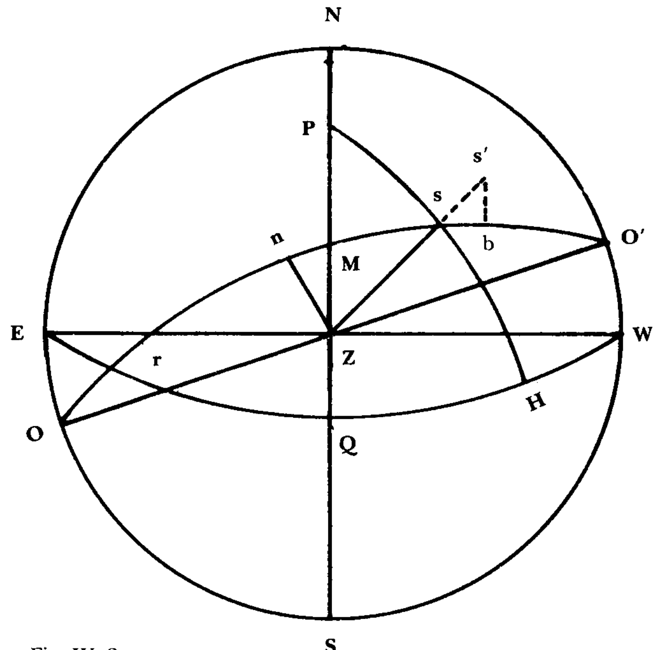


Fig. IX. 2

afternoon in the example given to illustrate which the figure is drawn). HQ is the right ascension corresponding to the segment of the ecliptic sM, which is found from the time to or from noon, by using the ascensional differences at the equator. (In the figure the time is afternoon.) *sr* is the longitude of the Sun at new moon. M*r* the longitude of m.e.p. = *sr* − sM, as stated for afternoon. Clearly, for forenoon, s being east of M, Mr = *s*r + Ms, as instructed.

MQ is the declination of M, (north in the fig.) ZQ is the latitude. MZ is the zenith distance. MZ = MQ − ZQ (in the fig.), *i.e.* when north declination is greater than the latitude, the latitude is subtracted from it, and the zenith distance is north. If M had been between Z and Q, then the north declination would be less than the latitude, and MZ would be equal to ZQ − MQ, and south. In the case when M is south of Q *i.e.* when the declination of M is south, it is clear that the zenith distance, MZ = MQ + QZ, and it is south, as stated.

It is to bring in all the above three cases that we interpreted *akṣaviyuta* in two ways, 'subtracting the latitude', and 'subtracting from the latitude'. But TS and NP take only the latter case, with the result that the former case is shut off. In verse 17, NP has corrected *madhyārka* as *madhyāhna*, which is not essential. The defect in the second quarter of verse 17 has been rectified here by the addition of the letter *kṣa* as *ranak(ṣa)rāśyudgamaiḥ*, *anakṣa* meaning *nirakṣa* or zero latitude, to give the sense required here. TS emends it as *nirakṣa* in the same sense and NP as *rantararāśyudgamaiḥ*.

[रविदृक्क्षेपः]

तिथ्यन्तविल(ग्न)ज्या काष्ठान्तज्याहता स्वलम्बहता |
मध्यज्याघ्नी व्यासाऽर्धभाजिता वर्गिता सा च || १९ ||

मध्यज्याकृतिविश्लेषितां पृथक् स्थाप्य मूलमेकस्याः ।
सवितुर्दृक्क्षेपाख्यं संस्मृत्यर्थं पृथक् स्थाप्यम् ॥ २० ॥

Dṛkṣepa of the Sun

19. Find the sine of the longitude of the Orient Ecliptic Point (o.e.p.) at new moon, multiply by the sine of maximum declination (of the Sun, 48′ 48″) and divide by the sine of the colatitude. (This is sine amplitude of o.e.p., called *Udayajyā.*) Multiply this by the sine of the zenith distance (z.d.) of m.e.p. already found, and divide by 120′. Square the result, and subtract from the square of the sine z.d. of the m.e.p.

20. Set the remainder in two places. In one place, find its square root. This is the sine of the zenith distance of the nonagesimal (z.d. of n.) called the Sun's *dṛk-kṣepa.* Keep this safe aside for future work.

The following is to be done:

(i) Using the *vināḍis* of ascensional differences of the place, the o.e.p. at new moon is to be found.

(ii) Sine amplitude of o.e.p. = sine z.d. of m.e.p. × 48′ 48″ ÷sine colatitude.

(iii) Sine (m.e.p. ~ nonagesimal) = sin z.d. of m.e.p. (ii) ÷ 120.

(iv) Square of sine (z.d. of n) = (sine z.d. of m.e.p.)^2 − (iii)^2.

(v) Sine z.d. of n = $\sqrt{(iv)}$.

Example 13. Continue example 10, given already lat = 10° 24′ and new moon is at nā. 20-40.

(i) Let us take it that using the ascensional differences of the place (given by chap.IV), the o.e.p. found is *rā*.5-27-56.

(ii) Sine amplitude of o.e.p. = sine *rā.* 5-27-56 × 48′ 48″ ÷ sin (90° − 10° 24′)

= sin 2° 4″ × 48′ 48″ ÷ sin 79° 36′

= 4′ 20″ × 48′ 48″ ÷ 118′.0 = 1′ 48″.

(iii) Sine (m.e.p. ~ n) = 28′ 9″ × 1′ 48″ ÷ 120 = 25″.

(iv) Sin^2 (z.d. of n) = (28′ 9″)^2 − (25″)^2 = 792′.25.

(v) Sin (z.d. of n) = $\sqrt{792.25}$ = 28′ 9″.

19a. A.B. विलग्ना ज्या
b. A. काष्टांत; B3. काषांत॰
c. B. मध्यमज्याघ्नी
20a. B1. ॰तति॰; B2.3. ॰तति॰. D. ॰विशे॰
b. B. ॰षितां; C.D. ॰षिता. A.B.D. स्थाप्या; C. स्थाऽपि. A.B. ॰मेकस्या
c. A. ॰र्दृक्षेपाख्यं; B. ॰र्द्रक्षेपाख्यं
d. B2. पृथक्थो य ॥

The following is the explanation of the rule: See fig. 2. There, n is the nonagesimal, i.e. o.e.p. *minus* three *rāśis*. Z is the zenith. n.z is the zenith distance of n, and sine nz, called the 'Sun's *dṛk-kṣepa*', is wanted here, to get the Moon's parallax in latitude. This *Siddhānta* takes the spherical triangle Z n M, right angled at n, to be approximately equal to a plane right-angled triangle, with the sines of the arcs as straight lines and finds the *dṛk-kṣsepa* by, $(\text{sine zn})^2 = (\text{sine MZ})^2 - (\text{sine nM})^2 = \sin^2$ z.d. of m.e.p. $- \sin^2$ (m.e.p. ~n). (The correct method has already been expounded by us in Chap.VI, when dealing with the solar eclipse according to the *Pauliśa*.) Sin (z.d. of M.e.p.) has been got already. The other quantity required, *viz.* sin (M.e.p. ~ n), is got by the well-known formulae relating to spherical right angled triangles, (already given by us), sin (M.e.p. ~ n) = sin (z.d. of M.e.p.) × sin MZn ÷ 120′. But, MZn = O′ZW = OZE, which is the amplitude of the o.e.p. Its sine, *Udayā*, given here = the declination of the o.e.p. × 120′ ÷ sine colatitude = sin longitude of o.e.p. × 48′ 48″ ÷ sin colatitude, as given in chap.IV.

[शङ्कुः]

दृ[क्]क्षेपकृतिं जह्यात् त्रिज्यावर्गात् ततोऽस्य यन्मूलम् |
लग्नाऽर्कविवरमौर्व्या गुणितं त्रिज्योद्धृतं शङ्कुः || २१ ||

Gnomon

21. Subtract from 14,400, the square of sin z.d. of n, (kept unused in the other place in the previous work), and find its square-root. Multiply this by the sine of the distance between the Sun and the o.e.p., and divide by 120′. The result, which is the sine of the Sun's altitude, is called *Śaṅku*, i.e. the Sun's *Śaṅku*.

∴ *Śaṅku* = $\sqrt{14{,}400 - \sin^2 (\text{z.d. of n})} \times \sin (\text{o.e.p.} \sim \text{sun}) \div 120'$. [$\sin^2$ (z.d. of n) has already been got, and kept apart]

Example 14. To complete example 10.

From Ex.13, by (i), o.e.p. = *rā.* 5-27-56, and by (iii), $\sin^2$ (z.d. of n) = 792.25, from Ex.10, Sun = *rā.* 2-0-0.

Śaṅku = $\sqrt{14{,}400 - 792.25} \times \sin$ (*rā.* 5-27-26 − *rā.* 2-0-0) ÷ 120′

= 116′ 39″ × sin (*rā.* 3-27-26) ÷ 120′

= 116′ 39″ × 106′ 7″ ÷ 120′ = 103′ 10″.

The rule is derived as follows: From fig. 2 it can be seen that the Sun's altitude is 90° − Zs.

∴ *Śannku* = Sine Sun's altitude = Cos Zs = Cos ZW × Cos ns ÷ 120′ (by the well-known formula, already given) = $\sqrt{\text{radius}^2 - \sin^2 \text{Zn}} \times \sin \text{Os} \div 120'$, (∵ ns is os − 90°). sin Zn is sine z.d. of n already found, and its square has already been got and kept apart for use here.

∴ *Śaṅku* = $\sqrt{14{,}400 - \sin^2 \text{z.d. of n}} \times \sin (\text{o.e. P} \sim \text{sun}) \div 120'$ as given by the author.

21a. A.दृक्षेप; B.दक्षेप. B.कृति A.जह्या
b. A.वर्गात्रितोस्प. A.०वन्मूलं; B.०पन्मूलं
c. B.विवरे
d. B.गुणित. A.त्रिज्योद्वृतं; B.त्रिज्योधृत

[लम्बितपर्वान्तः]

शङ्क्वङ्गुलाख्यविंशतिशतकृ(त्योर)न्तरेण विश्लेषात् |
स्थि(त)वर्गान्मूलं द्विनवकाहतं (त)द्वि(भ)ज्य कक्षाभ्याम् || २२ ||
भागविशेषा(त्ति)थिवत्तिथ्य(न्तनाम) पुनः पुनस्तत् स्यात् |
एवं मृग्यः कालस्तूत्पन्नो यावदविशेषः || २३ ||

Parallax-corrected New Moon

22-23. Subtract the square of the Sun's *śaṅku* got above from 14,400. From the remainder subtract the square of the Sun's *dṛk-kṣepa* kept apart in the previous work and find its square root, (technically called *Dṛggati*). Multiply this by 18 and divide by each of the *kakṣās* of the Sun and the Moon. Find the respective arcs (in minutes) and get their difference. Treat this as the minutes of *tithi* and find the *tithi-nāḍikās* for this. Subtract the *nāḍikās* from the time of new moon if forenoon, and add, if afternoon. The parallax-corrected new moon (p.c.n.) is got. Repeat the operation of finding the p.c.n., till there is no difference (in time) in two successive operations. This is the p.c.n. (to be used in the subsequent work).

Though there is no doubt about the idea here, it is difficult to get the idea from the words used, on account of several corrupt readings. In verse 22, a word is broken at the end of the third foot, and there are 18 *mātrās* in the fourth, sinning against the Ārya metre. In the same verse, in the second foot NP has emended *viśleṣāt* into *viśeṣitāt* against the manuscript readings, an emendation that is not needed. In the 23rd verse, *evam mṛgyaḥ kālaḥ* is a repetition. TS have succumbed to this difficulty and give the wrong interpretation that the difference between 14,400 and the square of the *śaṅku*, should be subtracted from the square of the *dṛk-kṣepa*, unaware that this is impossible since the latter would always be less than the former. We shall show this in the explanation. As for calling the Sun's *śaṅku* as 'digits of *śaṅku*' we have seen it being technically called so in chap. IV.

The method enunciated here is as follows:

(i) $Dṛggati = \sqrt{14{,}400 = śaṅku^2 - dṛk\text{-}kṣepa^2}.$

(ii) (*a*) Sin Sun's parallax in long. = 18 × (i) ÷ Sun's *kakṣā*

(*b*) Sin Moon's parallax in long. = 18 × (i) ÷ Moon's *kakṣā*.

From the two sines, the arcs should be obtained in minutes. The Moon's *minus* the Sun's parallax is the (effective) parallax in longitude.

22a. B.॰ख्यं विशति
b. A.शतकृशोनंतरेण; B.शततशोनन्तरेण (B2.त्तरेण; B3.तरेण)
D.विशेषि[त]ात्
c. A.B1.2.स्थिति
d. A1.B.हतं सद्विभाज्य
A1.कक्ष्याभ्यां

23a. A.विशेषस्त्रिथि; B.C.विशेषास्तिथि
b. A.तिथ्यर्धान्नामतः; D.तिथ्यर्द्धातामनः;
C.तिथ्यन्तान्नामतः; D.तिथ्यन्तोऽतः पुनः
d. A.स्नूत्पन्नो; B.तत्पन्नो
B.यावदवशेषः

(iii) *Nāḍis* of parallax = the parallax in longitude found in (ii) × 60 ÷ the motion of the *tithi* per day. Subtracting the *nāḍis* from new moon in the forenoon, and adding in the afternoon, the p.c.n. is got. Finding the m.e.p. etc. of the p.c.n., the work should be repeated upto getting the *nāḍis* in (iii). These *nāḍis* are to be subtracted or added to the original new noon. A better p.c.n. is got. Using this time the work may be further repeated for a still better approximation.

Example 15. To continue Ex. 10

In the last example the *śaṅku* got is 103′ 10″. In Ex. 10, the motion per day of the Sun and the Moon found are 57′ and 810″, the Sun's *kakṣā* found is 16,641 and the Moon's 1171.2. The square of the *dṛk-kṣepa* kept apart, is 792.25. From these:

(i) *Dṛggati* = $\sqrt{14{,}400 - (103\ 1/6)^2 - 792.25}$ = 54′ 27″.

(ii) (a) Sine Sun's par. in long. = 18 × 54′ 27″ ÷ 16,641 = 3″.6.

(b) Sine Moon's par. in long. = 18 × 54′ 27″ ÷ 1171.2 = 50″.2.

The Sun's parallax is arc of 3″.6 = 1′.7.

The Moon's parallax is arc of 50″.2 = 24′.0.

The parallax in longitude = 24′.0 − 1′.7 = 22′.3.

(iii) *Nāḍis* of par. = 22′.3 × 60 ÷ (810′ − 57′) = 1-47.

Since new moon is afternoon, adding to the time of new moon, the p.c.n. = *nā.* 20-40 + *nā.* 1-47 = *nā.* 22-27.

We shall repeat the operation for a better approximation. (The motions of the Sun and Moon per day, and their *kakṣās* need not be done again.)

The *nāḍis* of the p.c.n. after midday = 22-27 − 15-40 = 6-47 = 407 *vināḍis*. The right ascension, corresponding to the interval of 407 *vināḍis*, using the ascensional differences of zero latitude = 10° + 10° + 10° + 10° × 85.2 ÷ 108.8 (for *vināḍis* 105.4 + 107.6 + 108.8 + 85.2) = 37° 50′, after the Sun (= *rā.* 2-0-2, 2′ more for the 2 *nāḍis* later). ∴ The m.e.p. = *rā.* 2-0-2 + *rā.* 1-7-50 = *rā.* 3-7-52. The declination of m.e.p. = 23° 46′ north. The zenith distance of the point = 23° 46′ − 10° 24′ = 13° 22′, north. Sine z.d. of m.e.p. = 27′ 44″ . The o.e.p. at p.c.n. = *rā.* 6-8-48 (using as before the ascensional differences of 10° 24′). Since amplitude of the point = 7′ 34″. Sine (m.e.p. ~ n) = 27′ 44″ × 7′ 34″ ÷ 120 = 1′ 45″. Sine² (z.d. of n) = (27′ 44″)² − (1′ 45″)² = 765.89.

Sine (z.d. of n) = 27′ 40″.

Śaṅku = $\sqrt{14{,}400 - 765.89}$ × sine (*rā.* 4-8-46) ÷ 120′ = 91′ 1″.

Dṛggati = $\sqrt{14{,}400 - (91'\ 1'')^2 - 765.89}$ = 73′ 9″.

Sine Sun's par. in long. = 18 × 73′ 9″ ÷ 16,641 = 4″.8. Parallax = 2′.2.

Sine Moon's par. in long = 18 × 73′ 9″ ÷ 1171.2 = 1′ 7″.5. Parallax = 32′.2.

Relative parallax = 30′.0.

Nāḍis of parallax = 30′ × 60 ÷ 753′ = *nā.* 2-23.

Adding to time of new moon, the closer p.c.n. = *nā.* 20-40 + *nā.* 2-23 = *nā.* 23-3.

Repeating the work, the p.c.n. got will be about *nā.*23-20.

The rule is thus explained: It has been shown in the context of the *Pauliśa* solar eclipse that the relative total parallax is obtained by multiplying the relative horizontal parallax (ϖ) by sine zenith distance of the Sun (*dṛgjyā*) and dividing by the radius. In this *Siddhānta,* the horizontal parallaxes of the Sun and the Moon are got separately by dividing by their distances for the sake of exactness. But the Sun's *dṛgjya* is used for the Moon too, since the difference is very small in the neighbourhood of new moon, with the solar eclipse occurring. In fig. 2, *dṛgjya* = sin Zs, and the relative parallax = ss′. Its projection on the ecliptic, sl, is the relative parallax in longitude, by which (Moon − Sun) has got to be increased or decreased to get their apparent difference in longitude. In the figure, since s is west of n, it is subtractive, and p.c.n. is later, and therefore the *nāḍis* of parallax are additive. (When the Sun is east of n and parallax is additive, clearly the *nāḍis* are subtractive.) Since (Moon − Sun) is *tithi* element, the relative parallax is treated like *tithi,* and multiplied by 60 and divided by the daily motion to get the *nāḍis* of parallax.

Now, sl is found thus in this *Siddhānta:* $sl^2 = ss'^2 - s'l^2$. ($\because$ the triangle ss′l is right-angled at l, and so small that it may be considered plane.)

$= ss'^2 - ss'^2.\sin^2 l\, ss'$

$= ss'^2 - ss'^2.\sin^2 Zn \div \sin^2 Zs$ ($\because$ triangle Zns is right angled at n)

$= \varpi^2\, dṛgjya^2 - \varpi^2 \sin^2$ (z.d. of n) ($\because$ $ss' = \varpi \times dṛgjya$ = sin zs, and Zn is the z.d. of n)

$= \varpi^2$ (radius^2 − *Śaṅku*^{2} − sin^2 z.d. of n). (*dṛgjya*^{2} = radius^2 − *Śaṅku*^{2})

$\therefore sl^2 = \varpi\sqrt{120^2 - śaṅku^2 - \sin^2 \text{z.d. of n}}$

$= \varpi \times$ *dṛggati,* as given

But, ϖ = the Moon's horizontal parallax − the Sun's horizontal parallax. $\therefore$ the *dṛggati* is multiplied by each and then subtracted.

It has been said already, in previous two solar eclipse contexts, that the sine of the horizontal parallax is obtained by dividing the earth's radius by the respective distance. Since the author uses as the divisor not the actual distance but the respective distance divided by 43, the earth's radius also has to be taken divided by 43. The author takes 788 *yojanas* as the earth's radius, adopting the value of the *Āryabhaṭīya* and multiplying it by 3/2 to express it in the yojana measure of the *Ārdharātrika* etc. systems. (These systems give the earth's radius as 800 *yojanas.*) Dividing it by 43 we get 18.3, and the author gives it as 18, corrected to the nearest unit's place.

Further, since Zn is perpendicular to the ecliptic, Zs, the zenith distance of the Sun at any position on the ecliptic, is always greater than Zn, and, accordingly, their sines also, since the arcs are all less than 90°, i.e. (radius^2 − śaṅku^2) is always greater than sin^2 z.d. of n. Therefore, the interpretation of TS that the former is to be subtracted from the latter is wrong, as mentioned already. The need for successive approximation by repetition of work is plain.

[नतिः]

अविशेषाद् (दृक्क्षे)पं 'वस्वेक'घ्नं विभज्य कक्षाभ्याम् ।
लब्धान्तरचापांशा मध्यज्यादिग्वशेन नतिः ॥ २४ ॥

18

Parallax in latitude

24. Take the sine z.d. of n last got in the successive approximation, multiply by 18, and divide by the respective *kakṣās*. The respective sine parallax in latitude is got. The arc of their difference is the relative parallax in latitude and its direction is that of sine z.d. of m.e.p. (i.e. of M from Z.)

Since the sines are very small, it is immaterial whether the arcs are found first and their difference is taken, or whether the arc of the difference of the sines is taken, both being the same practically. But the latter will entail less work.

a) Sine parallax lat. of the Sun = 18 × sin z.d. of n ÷ Sun's *kakṣā*.

b) Sin parallax in lat. of the Moon = 18 × sin z.d. of n ÷ Moon's *kakṣā*.

(b) − (a) is the sine of the relative parallax in lat. whose arc is to be found, and its direction is that of M from Z.

Example 16. To continue example 10.

The sine z.d. of n, last got in the successive approximation in the last example is 27′ 26″ say.

(a) Sun's sine par. in lat. = 18 × 27′ 26″ ÷ 16,641 = 1″.8.

(b) Moon's par. in lat. = 18 × 27′ 26″ ÷ 1171.2 = 25″.3.

Sin relative par. in lat. = 25″.3. − 1″.8 = 23″.5.

Rel. par. in lat. = arc of 23″.5 = 11′.2, north, since M is north.

The rule is thus derived: The zenith distance of the nonagesimal, Zn, is the Sun's *dṛkkṣepa*. In the context of the solar eclipse, according to the *Pauliśa*, it was shown how the parallax in latitude (p.c.lat) is to be got by multiplying this *dṛk-kṣepa* by the relative horizontal parallax and using it as a correction to the Moon's latitude to obtain the corrected latitude. Here, the parallax is derived separately for each of the Sun and the Moon, for the sake of greater accuracy. Now, the direction of the nonagesimal and the sine of its zenith distance is the same as that of sine z.d. of M, and the direction of the apparent shifting of the Sun and the Moon by parallax, as resolved on the line of latitude, is the same as that of sine z.d. of n, (as ls′ in fig. 2). Therefore, the direction of the parallax correction is the direction of sine z.d. of M, as mentioned by the author. (In the fig. it is north.) Thus everything is explained.

ज्याविधिना विक्षेपं तत्कालं प्राप्य तेन सहितोना |
स्पष्ट[ा] नतिः प्रमाणैः स्वैस्स्वैर्ग्रासं स्थितं च वदेत् || २५ ||

25. The Moon's latitude at the time taken is to be got by using the sine (of Moon ~ Rāhu), and this is to be added to or subtracted from the parallax correction in latitude (according to their direction). This is the parallax-corrected latitude (p.c. lat.). This is to be got separately for each of the times separately and from them the times of total obscuration and total duration are to be got.

24a. A.दृक्षेपं; B.दृक्षेप
b. B.चस्वेकघ्नं (B2.3.०घ्नं) d. B.ज्यादिग्व

25a. B.विक्षेप
b. A.प्राथ c. A.B.स्पष्टनति
d. A.स्वैस्वैग्रसं; B.स्वैस्वैर्ग्रामं
D.स्थितिं

The maximum latitude is given in verse 6 to be 270′. The use of sine (Moon − Rāhu) has been already indicated in the context of the *Romaka*, and therefore only indicated here. In correcting, like directions are additive, and unlike directions subtractive, the resulting direction being that of the greater. The parallax-corrected latitude is to be got for each of the time of first contact, last contact, and middle, the last serving for immersion and emergence too, as these times are near enough to the middle. The separate computation of the corrected latitude suggests that the *nāḍis* of parallax also are to be computed separately for the different times. Thus, the following is to be done:

(i) The uncorrected latitude = 270′ × sine (Moon − Rāhu) ÷ 120 = sine (Moon − Rāhu) × 9 ÷ 4. (If Moon − Rāhu) is less than 6 *rāśis*, the latitude is north, otherwise south. Rāhu here means the Head of Rāhu).

(ii) Parallax-corrected latitude = latitude $\underset{\sim}{+}$ relative parallax in latitude (+ if of the same direction, and ∼ if of different directions, the resulting direction being that of the greater).

Example 17. (To continue Ex.10,) find the parallax-corrected latitude at the final parallax corrected new moon, i.e. at nāḍi 23-20.

This time is *nāḍis 2-40* later than new moon. So, from the data given in Ex. 10, Rāhu-head = *rā.* 7-29-24, and Moon = *rā.* 2-0-0 + 810′ × 2 2/3 ÷ 60 = *rā.* 2-0-36. Moon − Rāhu = *rā.* 6-1-12. From this,

Moon's latitude = 9 × sine (*rā.* 6-1-12) ÷ 4 = 5′.7, south. (∵ Moon − Rāhu-head) > *rā.* 6-0-0.)

(ii) Parallax corrected lat. = 5′.7 ∼ 11′.2 = 5′.5, north (∵ of different directions, north being greater.)

These rules have been explained before.

[विमर्दकालः]

अवनतिवर्गं जह्याद् रवीन्दुपरिमाणयोगदलवर्गात् |
तन्मूला(त्तु) द्विगुणात्(ति)थिभुक्तवदादिशेत् कालम् || २६ ||

Duration of the eclipse

26. Subtract the square of the parallax - corrected latitude from the square of the sum of the semi-diameters of the Sun and the Moon and find the square root. Double this, and find the time for it, treating it as the motion of *tithi*. (The duration of the eclipse it got.)

This verse has already occurred as verse 16 of chap. VIII and fully explained there. The only difference is two mis-readings here.

Example 18. To continue Ex. 10.

In Ex.11, the angular diameter of the Sun has been found to be 31′, and of the Moon, 33′ and the daily motion of the *tithi* 753′. The parallax-corrected lat. has been found to be 5′.5. From these,

Duration in *nāḍikās* = $2 \times 60 \times \sqrt{(31 + 33)/2 - 5.5^2} \div 753 = 2 \times 60 \times 31.52 \div 753$ = *nā.*5-1.

26b. B3.॰न्दुः. B.परिपरिमाणग्दल (B3.॰योगदल) c. A.B.मूलात्त d. A.B1.2.तिथिभुक्ति. B.॰वदादिकेत्कालं

It has already been mentioned that half the duration subtracted from the final parallax-corrected new moon is the beginning and added to it is the end of the eclipse. Further, if the difference of the semi-diameters is used in the work, instead of the sum, the duration of total eclipse is got. Here, if the Moon's is greater, there is actual total obscuration. If the Sun's is greater, there is annular eclipse. The author expects us to be conversant with these things.

तिथ्यवना(मो) ग्रहणादिना(म)विश्लेषि[तो यु]तः स्थित्याम् |
गोलाऽन्यत्वे देयस्त्ववनामो [मौ]क्षि(क)स्यैवम् || २७ ||

27. Find the *nāḍis* of parallax for the time of the beginning. If the time of beginning and the new moon are both in the forenoon or both in the afternoon, find the difference of the *nāḍis* of parallax and add it to the half duration to get the correct half duration to be subtracted from the time of the corrected new moon. If one is before noon and the other afternoon, add the nāḍis of parallax, and add it to the half-duration to get the correct half-duration (to be subtracted from the time of parallax-corrected new moon). Do the same for the time of the end of the eclipse, (to find the correct half duration to be added to the parallax-corrected new moon, to get the correct last contact).

The following example will make the meaning clear.

Example 19. To continue Ex. 10.

We have already obtained, par.c. new moon = *nā*.23-20, parallax-correction for new moon = *nā*.2-40, and the total duration *nā*.5-1. Applying the half duration on both sides of p.c.n, the approx. time of first contact = *nā*.20-50, last contact = *nā*.25-51. The parallax correction in time for first contact using verses (22-23) is *nā*. 1-50. As both the new moon and time of first contact are in the same part of the day, i.e. afternoon, the difference between their parallax correction = *nā*.2-40 − *nā*.1-50 = *nā*.0-50. This is to be added to the half duration to get the first half duration. Adding, *nā*.2-30 + *nā*.0-50 = *nā*.3-20. Subtracting this from the parallax-corrected new moon, the correct time of first contact = *nā*. 23-20 − *nā*. 3-20 = *nā*. 20-0, after sunrise.

Next, the parallax-correction for time of approx. last contact is *nā*.3-30. As both new moon and last contact are in the afternoon, subtracting the corrections, for both from each other, we have *nā*.3-30 − *nā*.2-40 = *nā*.0-50. Adding this to the half-duration we have, *nā*.2-31 + *nā*.0-50 = *nā*.3-21, for the correct second half duration. Adding this to the p.c.n, the correct time of last contact = *nā*.23-20 + *nā*.3-21 = *nā*.26-41 after sunrise.

The following is the explanation of the rules for the correction given here and the justification for our interpretation. At first the duration is given neglecting the effect of parallax on the time. If the parallax is taken into account, the duration will always be longer than otherwise, as we have said. This can be seen from the following consideration. Let us take the case when the end of new moon

27a. A.B.नाम
b. A.B.C.D.॰दिना च वि॰. A.B.विश्लेषित; C.D.विश्लेषितः
c. B.॰न्य चेदेय
d. A. स्त्वनामो A.B. Hapl. om of मौ

is before noon. The first contact being earlier still, its interval from noon is greater, and therefore its *nāḍis* of parallax too is greater than those of the new moon. Since both are subtractive, the first half duration is lengthened, the first contact happening earlier. Therefore the difference is to be added to the duration. In the case taken, the last contact may happen before noon or after noon. If before noon, the interval from noon upto the last contact is less than that upto new moon. Therefore the *nāḍis* of parallax of the last contact is less than those of the new moon, and both are subtractive. Therefore the second half duration also is lengthened, the last contact happening later. So the difference is, here too, additive to the duration.

If the last contact is afternoon, the *naḍis* of parallax are clearly additive to the time of last contact, and the last contact happens later. But the parallax-corrected new moon occurs earlier, and so the second half-duration is lengthened both ways, and so the sum of the parallaxes is added to the duration. Thus in all three possibilities of the first case, there is only additive correction.

Let us now take the second case, *viz.* that the new moon occurs after noon. Clearly what is said for the first contact in the first case applies to the last contact in the second case, and vice versa, but the additiveness and subtractiveness alone have to be interchanged. Therefore, here too, in all three possibilities the differences or sums, have to be added to the duration, as we have said in giving the meaning of the verse. Not understanding the above, TS have interpreted the verse in such a way that the instruction will result in lessening the duration, which is contrary to facts.

Now, for the readings. In the second foot of the verse three *mātrās* are missing, and to restore them we have read *viśleṣita* as *viśleṣito yutaḥ* in accordance with the meaning. The emendation, by TS and NP, of the manuscript reading *viśleṣitasthityām* into *viśleṣitaḥsthityā* does not express the intended idea fully. In the fourth foot two *mātrās* are missing, and to restore them we have read the meaningless *nāmokṣi* as *nāmo maukṣi.*

To conclude: In the introduction to this chapter we said that the Sun, Moon, and Rāhu, together with the methods of computing them are better in the *Saura* than in the *Romaka.* Now, we have seen that in the computation of the solar eclipse also, the *Saura* excels. For instance, the mean angular diameters of the Sun and the Moon are 30′ and 34′ according to the *Romakas,* while they are 32′ and 32′ according to the *Saura,* very near the correct 32′ and 31′, respectively. Computing true diameters and the parallax using the distance of the instant of eclipse, and using the true motion of the time of eclipse for getting the duration etc. are commendable in the *Saura.* Getting the sine z.d.n. by using the sine of the zenith distance of m.e.p. is a better method than that used by the *Romaka,* as also the method of successive approximation for various things like parallax in time of new moon etc. The abandoning of the *Romaka's* faulty correction of the Moon's position in its own orbit, is itself praiseworthy. With such good features, the *Saura is easily the best of the five Siddhāntas.*

[इति पञ्चसिद्धान्तिकायां वराहमिहिरविरचितायां
सूर्यसिद्धान्तेऽर्कग्रहणं नाम नवमोऽध्यायः][1]

1. Col. A.B.D. इति (B. om इति) सूर्यसिद्धान्तेऽर्कग्रहणं
(B. णनाम) नवमोध्यायः |
C. इति सूर्यसिद्धान्ते सूर्यग्रहणं नाम नवमोऽध्यायः |

Thus ends Chapter Nine entitled 'Saura-Siddhānta: Solar Eclipse' in the Pañcasiddhāntikā composed by Varāhamihira

Chapter Ten

SAURA-SIDDHĀNTA — LUNAR ECLIPSE

१०. दशमोऽध्यायः

सौरसिद्धान्तः — चन्द्रग्रहणम्

Introduction

In this chapter the method of computing the lunar eclipse according to the *Saura Siddhānta* is given. Since the true Sun and the Moon and Rāhu, the true distances of the Sun and the Moon, and the Moon's angular diameter and latitude, have already been given in chap. IX, the angular diameter of the Shadow alone is given here, as also the computation of the times of contacts etc. The last three stanzas give the amount of eclipse at a desired time, as also the beginning and end of total phase of the eclipses, both of the Sun and the Moon.

[तमोबिम्बमानम्]

रविकक्षा नवतिगुणा 'षडष्टदस्रो'द्धृतेन्दुकक्षायाः |
छेदः 'षट्त्रि'घ्नाया ल(ब्धे)नोनश्च षड्वर्गः || १ ||
'वियदर्क'गुणे शशिक(क्ष्य)या हृते कार्मुकं त(मो)व्यासः || २ a ||

Diameter of the Shadow

1-2a. Multiply the Moon's true distances in its orbit by 36, and divide by the Sun's true distance multiplied by 90 and divided by 286. Subtract this result from 36, multiply by 120, divide by the Moon's true distance and get the arc of the resulting sine. This is the angular diameter of the Shadow.

The following is asked to be done:

(i) 'Result' = 36 × Moon's true dist. ÷ (90 × Sun's true dist. ÷ 286)

= 36 × Moon's true dist. × 286 ÷ (90 × Sun's true distance).

(ii) Sine angular diameter of Shadow = (36 − 'result') 120 ÷ Moon's true distance.

Or, simplifying, this is equal to:

{36/Moon's true distance − (36/Sun's true distance) × 286/90} × 120

= 4320/Moon's true distance − 13,728/Sun's true distance.

1a. A. कक्ष्या. B. नवतीगुणा
b. A. द्रुतेन्दु. A.B1.3. कक्ष्यायाः C. षडश्व
c. B1.3. षद्रिघ्नाया
d. A. लद्योनो; B1.3. लधोनातश्च

2a. B1.3. वियदर्वगुणे
b. A.B. कक्ष्याया; C.D. कक्ष्या. A. तमोर्व्यासः;
B1.3. तयोव्याघ्रः

Or, (since the arc is small, multiplying this by 3438 and dividing by 120), the angular diameter of the Shadow in minutes = 1,23,768 ÷ Moon's true distance − 3,93,307 ÷ Sun's true distance.

Example 1. On a certain day at the time of full moon (T) the true Sun is rā.10-0-0, the true Moon is rā.4-0-0, Rāhu Head is rā.3-25-0, the Sun's motion per day for the time is 60′, and the Moon's 780′. *Compute the lunar eclipse.*

The Sun's true dist. = 9,48,558 ÷ 60 = 15,809 (by IX.15).
The Moon's true dist. = 9,48,680 ÷ 780 = 1216.3 (by IX.15).
The Moon's angular dia. = 38,640 ÷ 1216.3 = 31′.77 (by IX.16).
The Moon's lat. at T = 9 × sine (*rā*.4-0-0 − *rā*.3-25-0) ÷ 4 = 23′.5, north.

From the true distances got above, the angular diameter of the Shadow = 1,23,768 ÷ 1216.3 − 3,93,307 ÷ 15,809

= 101′.76 − 24′.88 = 76′.9.

The following is the explanation of the method for finding the Moon's angular diameter: The actual diameter of the Shadow is the diameter of the circular section of the Shadow-cone (formed by the earth intercepting the Sun's light,) at the Moon's orbit, at the time of full moon. This is represented in fig. 1, below by U′U″.

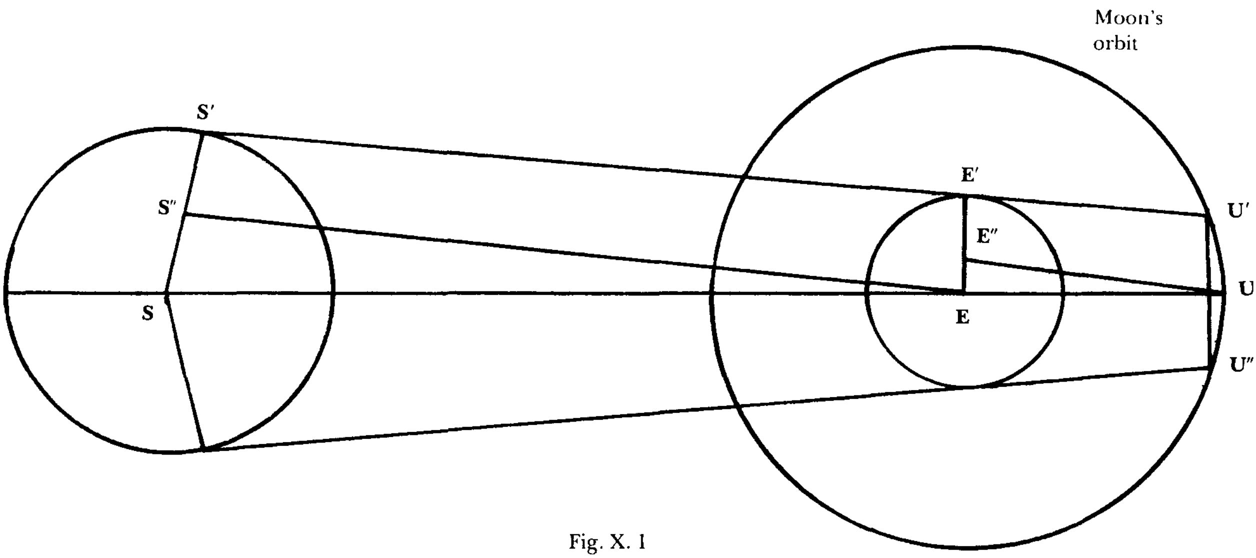


Fig. X. 1

The angle subtended by this at the centre of the earth, E, is the angular diameter desired to be computed here. In the figure, S is the centre of the Sun, E, that of the Earth, and U that of the Shadow section. SS′ is the Sun's radius, EE′ is the Earth's, and UU′ is that of the Shadow. SE is the true distance of the earth from the Sun, and EU, that of the Moon from the earth. S′E′U′ is the direct common tangent to the orbs of the Sun and the Moon. As the distance are very great when compared with the radii, EE′, SS′, and UU′ are practically parallel. Draw ES″ parallel to E′S′, and U′E″ parallel to U′E′. The triangles, ES″S and UE″E, are similar. Therefore,

E″E/EU = S″S/SE.

$\therefore$ E″E = S″S × EU/SE = EU × (S′S − S′ S″)/SE

= EU × (S′S − E′E)/SE.

In order to get the angular diameter of the Shadow, we require the radius of the Shadow, UU′,

= EE′ − EE″ = EE′ − {EU (SS′ − EE′)/SE}

= 18 − Moon's true dist. × (Sun's radius − 18) ÷ Sun's true dist.

= 18 − Moon's true dist. × {18 × 5,14,787 ÷ (2 × 18 × 3438) − 18} ÷ Sun's true dist. (Here, 18 is the number obtained by reducing the earth's radius by 43, and given by the author in giving the parallax, see IX.23.)

18 × 5,14,787 ÷ (2 × 18 × 3438) is the Sun's radius, since, of two orbs, the parallax as viewed from one is the angular semi-diameter as viewed from the other. Therefore:

Sun's minutes of parallax: Sun's angular semi-diameter in minutes :: 18: Sun's reduced radius.

But the Sun's minutes of parallax = 18 × 3438 ÷ the Sun's true distance, and the Sun's semi-diameter in minutes = 5,14,787 ÷ (2 ×the Sun's true distance) = 18 − Moon's true distance × 18 × 284.4 ÷ (90 × Sun's true dist.)

Since, sine angular diameter of the Shadow is got by multiplying the radius by 2, and the max. tabular sine and dividing by the Moon's true distance, sine angular diameter of Shadow = {36 − Moon's true dist. × 36 ÷ (90 × Sun's true dist. ÷ 284.4)} × 120 ÷Moon's true distance, almost the same as the author has given, but with 284.4 instead of 286.

If the number had been 17.9 instead of 18 taken as a whole number for convenience, then we shall get 286 itself, as given by the author. We have already shown that the formula can be simplified. The author must have given it in the involved form for indicating the geometrical construction by way of proof.

When the numbers occurring are seen to be correct in the way shown by us, it is quite improper for TS to read *ṣaḍaṣṭadasra (278) as ṣaḍaśvadasra* (276) and to agree with this, making the Sun's reduced diameter as 146, in their proof, instead of the correct 149.73, got by dividing 5,14,787 by 3438.

[विमर्दकालः]

चन्द्रतमोव्यासयु(तिं) द्वाभ्यां हृत्वा ततो वर्गात् || २ b ||
विक्षेपवर्गहीनादासन्नपदे 'वियद्द्विचन्द्र'घ्ने |
सूर्येन्दुभुक्तिविवरो(द्धृ)ते स्थिते(र्ना)डिका लब्धाः || ३ ||
प्रग्रहणे(न्दोः) कृत्वा विक्षेप[म]तोऽनया स्थि(ति)र्भवति |
एवं भूयो भूयः स्थित्य(वि)शेषः कृतो यावत् || ४ ||

Duration of the Eclipse

2b-3. Add the angular diameters of the Moon and the Shadow, divide by two, and square it. Subtract the square of the Moon's latitude from this, and find

the square root. Multiply this by 120 and divide by the difference of the motions per day of the Sun and the Moon pertaining to the time of eclipse. The duration of the eclipse is got in *nāḍikās*.

4. Find the Moon's latitude at first contact and using this find a more correct duration. Repeat this till there is no difference between the previous and the next durations.

Note: Though the total duration alone is given here, we are expected to know how to find the first and last contacts from this, from previous contexts. In the successive approximation, what is said for the first contact must be taken for the last contact also. Therefore the following is asked to be done:

(i) Rough duration $= 120\sqrt{(\text{half-sum of angular diameters})^2 - \text{lat.}^2} \div$ difference of instantaneous daily motions.

(ii) T ± half (i), are the rough first and last contacts.

(iii) Using the latitude of the rough first contact and repeating (i) gives successively better first contacts.

(iv) Using the latitude of the rough last contact, and repeating (i), gives successively better last contacts. (It should be noted that the shorter the duration the greater are the number of repetitions required.)

Example 2. Continue Ex.1.

(i) Rough duration in *nāḍis* $120\sqrt{\{(76.9 + 31.77)/2\}^2 - 23.5^2} \div (780 - 60)$

$= 120\sqrt{54.34^2 - 23.5^2} \div 720 = 120 \times 49 \div 720 \div$ *nāḍis* 8-10.

(ii) Rough times first and last contacts = T − *nā*.4-5: T + *nā*.4-5.

(iii) The Moon at rough first contact = *rā*.3-29-6.9,
Rāhu then = *rā*.3-25-0.2.

Moon − Rāhu = 4° 6′.7.

From this the Moon's latitude is 19′.35, north.

Using this, a more correct duration for first contact $= \sqrt{54.34^2 - 19.35^2} \times 120 \div 720 =$ *nā*.8-28.

Subtracting half this from the time of full moon, the first contact is at T − *nā*.4-14. There is no need to repeat, since the duration is long.

(iv) The Moon at rough last contact is *rā*.4-0-53.1, and Rāhu then, *rā*.3-24-59.8. From this the Moon's lat. is 27′.65, north. Using this, a more correct duration for last contact $= \sqrt{54.34^2 - 27.65^2} \times 120 \div 720 =$ *nā*.7-48. Adding half this to full moon time, the last contact is at T + *nā*.3-54. There is no need to repeat.

The method has been explained several times before, which need not be repeated here. As for understanding that the successive approximation is for getting the last contact also, though men-

2c. A.B.युतिः. B1.3.हच्या; B3.हत्या
3b. A.B.वियद्वि
d. A.B.धृते. A.B.C.D.स्थिते for स्थिते; A.लब्धा
4a. A.B.C.प्रग्रहणेन्दुः
b. A.B.om.म. A.B.स्थितैः
d. A.B.स्थित्यवशेषः

tioned only for the first contact, the two common statements *anayā sthitir bhavati* and *sthityaviśeṣaḥ kṛto yāvat*, indicate this.

[इष्टकालग्रासः]

अर्केन्दुभुक्तिविवरं वाञ्छितनाडीहतं तु षष्टिहतम् ।
स्थितिलिप्तास्ताभ्यस्त(त्त)त्कालेन्दोश्च वि(क्षे)पात् ॥ ५ ॥
कृतियोगपदं शोध्यं शशिराहुकला(प्र)माणयोगदलात् ।
यच्छेषं तद् ग्रस्तं ज्ञेयं तत्कालमर्केन्द्वोः ॥ ६ ॥

Obscuration at any desired moment

5-6 Take the *nāḍis* before or after full or new moon upto the times for which the amount eclipsed is wanted. Multiply this by the difference of the Sun's and Moon's daily motions, (mentioned above), and divide by 60. The 'corresponding minutes of arc' are got. Square this, square the Moon's latitude for the moment, add them, and get the square root. Subtract this from the half-sum of the diameters of the eclipsing and the eclipsed bodies. The remainder is the minutes of arc eclipsed, at the moment taken, of the Moon in the case of the lunar eclipse, and of the Sun in the case of the solar eclipse.

It is clear that by 'corresponding minutes of arc' is meant here, the distance in minutes between the Moon and the shadow, measured along the ecliptic. From the instruction it is clear that the *nāḍis* taken is the interval between full or new moon and the moment for which the amount of eclipse is wanted. It is clear from the context that the Shadow is meant by the word Rāhu. Though from the mention of the Shadow, and the Moon's latitude without any mention of parallax, this seems to be given for the lunar eclipse only, the expression *arkendvoḥ* at the end shows that this is meant for the solar eclipse also. The author thinks that the reader has acquired sufficient knowledge, by now, to make the necessary changes when applying the rule to the solar eclipse. Therefore, in the case of the solar eclipse, the amount eclipsed is got by using in the rule, the parallax-corrected latitude for latitude, the Sun's and the Moon's angular diameters for those of the Moon and the Shadow, and the parallax-corrected difference of daily motions for the mere difference of daily motions. Thus, the following is instructed to be done:

A. To find the amount eclipsed in the case of the Moon

(i) "Corresponding minutes of arc" = difference of instantaneous daily motions of Sun and Moon × interval in *nāḍis* from full moon ÷ 60.

5c. C.तत्स्थितिलिप्ताविवरात्. A.B.ताभ्यस्ता; D.ताभ्यस्तु
d. A.तान्तत्कालेन्दोश्च (A2.तात्तत्का). AB.विशेषात्
6a. B.ततियोग°
b. B.शशिराज्ञ (B2.B.ब्ज) कलां. A.C.D.कलाद्यमान;
B.कलाघमाण
c. A1.यछेपं; A2.यछेषं
d. B1.3.मर्केन्दोः

(ii) Distance in minutes between the centres of the Moon and Shadow $= \sqrt{(\text{i})^2 + (\text{the Moon's latitude at the given time})^2}$.

(iii) The amount eclipsed in minutes = half-sum of angular diameters of the Moon and Shadow − (ii)

B. To find the amount eclipsed in the case of the Sun.

(i) "Corresponding minutes of arc" = The minutes obtained as by A (i) × the half duration not corrected for parallax ÷ the half duration corrected for parallax. (This will be a little approximate, but has been given for case of computation, since the two times are known.)

(ii) Distance in minutes between the centres of the Sun and the Moon $= \sqrt{(\text{i})^2 + (\text{Parallax-corrected lat. of time})^2}$.

(iii) The amount eclipsed in minutes = half sum of angular diameters of the Sun and the Moon − (ii).

Example 3. Continuing Ex. 2, find the amount of the moon eclipsed 3 nāḍis after T.

A. (i) Corresponding minutes of arc = (780′ − 60′) × 3/60 = 36′

(ii) Distance between centres $= \sqrt{36^2 + 26.6^2} = 44'.76$ (having found that the Moon's lat. at the moment is 26′.6).

(iii) Amount eclipsed = 54′.34 − 44.76 = 9′.6.

Example 4. At a certain solar eclipse the difference of Sun and Moon's motions is found to be 720′, the parallax-corrected latitude, 2 nāḍis before the parallax-corrected new moon, is found to be 15′, the sum of the semi-diameters is 31′.9, the un-corrected half duration is nā. 2-30, and the corrected half duration is nā. 3. Find the amount of the Sun eclipsed, at 2 nāḍis before the parallax corrected new moon.

(i) Corresponding minutes of arc = (720 × 2 ÷ 60) × *nā*.2 1/2 ÷ *nā*.3 = 24 × 5 ÷ 6 =20′ (nearly).

(ii) Distance between centres $= \sqrt{20^2 + 15^2} = 25'$.

(iii) The amount eclipsed = 31′.9 − 25′ = 6′.9.

The following is the explanation of the method: Let us first take the case of the lunar eclipse. At full moon, the Moon and the Shadow are in conjunction, i.e. they have the same true longitude. Since the Shadow has the same motion as the Sun, the interval between them for any interval of time before or after full moon is the same as the interval in *tithi* proportionate to the time interval. Therefore there is the proportion, if for 60 *nāḍis* there is the difference of the daily motion, how much for the interval in time. So the difference in motion is multiplied by the given time and divided by 60. Since the motions are measured along the ecliptic, the interval in minutes along the ecliptic is got, corresponding to the time interval. The distance between the centres is got thus:

In fig.2, S is the centre of the Shadow and M is that of the Moon. SM′ is the 'corresponding minutes' got for the interval in time. MM′ is the Moon's latitude at the given moment. Since MM′ is directed towards the pole of the ecliptic, the triangle SM′M is right-angled at M′. Since the triangle, being small, can be treated as a plane triangle, we have, by the Pythagoras Theorem, the distance between the centres, $SM = \sqrt{SM'^2 + MM'^2} = \sqrt{\text{corres. minutes}^2 + \text{latitude}^2}$, as given. The amount eclipsed in minutes = Rr = SR − Sr = SR − (SM − Mr) = SR + Mr − SM = sum of semi-diameters of the Shadow and the Moon, minus the distance between their centres.

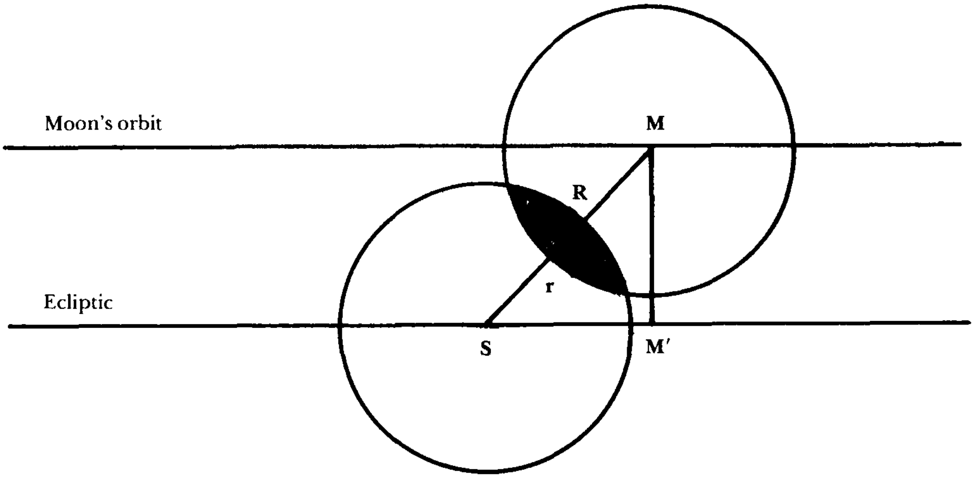


Fig. X. 2

What has been proved for the lunar eclipse can be taken for the solar eclipse also, with the necessary changes. The difference in motions should be here corrected for parallax and used. That this corrected difference is always less than the uncorrected will be clear, when we consider that always the parallax-corrected half duration is always greater than the uncorrected, which we have already proved. Therefore it is clear that by multiplying the "corresponding minutes" by the uncorrected half duration, and dividing by the parallax-corrected half duration, will give the parallax-corrected "corresponding minutes". It is also clear that in the case of the solar eclipse we must use in the proof the parallax-corrected latitude in the place of the uncorrected latitude, the Sun for the Moon, and the Moon for the Shadow. When this is done, the proof is exactly similar to that for the lunar eclipse.

Another thing is to be noted. The Hindu astronomers took the amount of eclipse at full moon or corrected new moon as the maximum and called it the magnitude, (*grāsa-pramāṇa*), though actually this is only very nearly the maximum and the actual maximum occurs a little earlier or later. If we take this full or new moon itself for doing the present work, since the time interval is zero, and thereby the 'corresponding minutes' are also zero, the latitude itself becomes the distance between the centres. Therefore we got that the amount eclipsed in this case (i.e. the magnitude) is to be got by subtracting the latitude of full or corrected new moon, from the half sum of the angular diameters, as already given.

Now for the readings: *vāñcchitanāḍī* ('desired time') is meant here the interval in time from the full or new moon, either before or after. But TS have taken the expression to mean 'the desired point of time', and in order to get the meaning of 'interval' that is wanted for use, have emended the already correct *sthitiliptāstābhyas tat* into *tatsthitiliptāvivarāt*, which is unnecessary. Another thing must be said here. If the reading had been *tithiliptāḥ* instead of *sthitiliptāḥ* given by the manuscripts and accepted by us, it would have been better; for this would mean the minutes of *tithi*, as indeed these are, being part of a *tithi* by nature.

[पूर्णग्रासकालः]

अन्त्याद्ययोर्विशेषा(द)वनतिविक्षेपवर्गविवरपदम् |
द्विगुणं तिथिवत् कृत्वा विमर्दकालोऽर्कचन्द्रमसोः || ७ ||

Time of total obscuration

7. Take the difference of the angular semi-diameters, instead of their sum. Square it, subtract the square of the parallax-corrected latitude (in the case of the solar eclipse) or of the latitude (in the case of the lunar,) find the square root, double it, and treat it as *tithi,* (i.e. multiply by 60, and divide by the difference of the parallax-corrected daily motions for the solar eclipse, or of the mere daily motions in the case of the lunar). The time of total obscuration is got.

In short, everything done for the duration, using the difference of the semi-diameters instead of the sum, is to be done for this. Halving this time and subtracting from or adding to the corrected new moon or full moon gives the first approximate times of immersion and emergence. In the case of the lunar eclipse, successive approximation should be done. In the solar eclipse this is not necessary, because the times of immersion and emergence are very close to the corrected new moon. The parallax-correction for the motion alone need be taken into account and that once for all.

Another point to be noted is that, in the solar eclipse, if the Sun's angular diameter is greater than the Moon's, instead of a total eclipse there will be an annular (ring-like) eclipse, since the Moon will not be big enough to hide the Sun. The times got, in this case, give the beginning and end of the annular phase. Also, the given examples cannot be continued to illustrate this section, because under the conditions got there will be no total phase, since the latitudes are greater than the difference of the semi-diameters. The proof of the rules given here has already been given in connection with the eclipses according to the *Vāsiṣṭha* and *Pauliśa* with graphical illustrations.

Now for the text, and readings: The text does not instruct that the difference of the semi-diameters should be squared before adding to the square of the latitude. But mathematical principles indicate it, since the addition of an unsquared quantity with a squared one is unwarranted. We have corrected *viśeṣāvavanati* into *viśeṣādavanati* while TS have corrected it into *viśeṣāddalanati* and NP into *viśeṣārdhabhapati.* It is clear that they have taken more liberty with the text than necessary, and it is also purposeless.

[इति पञ्चसिद्धान्तिकायां वराहमिहिरविरचितायां
सूर्यद्धिान्ते चन्द्रग्रहणं नाम दशमोऽध्यायः |][1]

1. Col. A.D. चन्द्रग्रहणं दशमोऽध्यायः; B. चन्द्रग्रहणे.दशमोध्यायः C. इति चन्द्रग्रहणं नाम दशमोऽध्यायः

Thus ends Chapter Ten entitled 'Saura-Siddhānta: Lunar Eclipse' in the Pāncasiddhāntikā composed by Varāhamihira

7a.b. A. अंत्पाययो र्विशेषाववनति; B. अताद्ययार्विशेषवनत्ति
C. विशेषाद्दलनति; D. विशेषार्धभपति

b. B1.3. विचरपदं c. B1. कृचा d. B. कालो चन्द्र

Chapter Eleven

ECLIPSE DIAGRAM

एकादशोऽध्यायः
ग्रहणपरिलेखः

Introduction

Since the distinction among eclipse-types, and various ideas mentioned therein, will not be clear without graphical representation, the author 'follows up' the chapters on eclipses with one solely devoted to this subject.

[अपमण्डलाद्यङ्कनम्]

यष्ट्या वि(द्धा)ङ्गुलया वृत्तं परिलिख्य संप्रसार्य दिशम् |
अ(न्त्या)द्यदलैक्येना(थ य)दपरमर्धेन चाद्यस्य || १ ||

चन्द्रा(म्ब)रान्तरांशोत्क्रमज्यया ज्यां निहत्य वैषुवतीम् |
'खार्का'शांशा(नु)दयास्तमयोदग्याम्यतो दद्यात् || २ ||

Marking the ecliptic etc.

1. Using the stick-instrument with notch-marks of digits, draw the circle called the 'sum-circle', having for its radius the half sum of the diameters converted into digits. Mark the east-west and north-south lines. (E-W, and N-S, in fig. 1). Similarly, using the semi-diameter of the eclipsed body, converted into digits as radius, draw the 'eclipsed body circle', concentric with the sum-circle. (See fig.)

2. Find the versine of the hour-angle (of the Moon at mid-eclipse) and multiply this by the tabular sine of the latitude of the observer and divide by 120. Find the arc of degrees of the resulting sine. If the hour-angle is east, lay the degrees north of the east-point, if west, south of the east-point. The east-point with reference to the equator is thus got. (E′, in the figure. E′−W′ is the corresponding east-west.)

1a. B.षष्ठया A.B.विधित्र्यंगुलयाः; C.D.विध्यङ्गुलया
b. A1.वृत्त; B1.3.वृतं B3.दिशां; C.D.दिशः
c. A.अंताद्यदलैक्योना; B1.3.अन्ताद्युदलैक्योनात्
c-d C.D.॰दलैक्येनाद्यमपर
d. A.यदपर; B1.3.पदपर B2.चापस्य
2a. A.चंद्रावरात्तरांशो; B.चन्द्रावतरांशो; D.न्तोंशात्
b. B.तक्रमज्याथाज्यां A.B.विहत्य B.वैषुवती
c. A.खार्कांशादुदया; B.खा (B1.3.ख) कांशांशाम्बुरदया;
d. A.दस्त्र मयोतुदग्याम्यतोः (A2. gap for मयो तु दग्); B.स्तमयोनुदग्याम्यतो; D.स्मयात्त्दग्याम्यतो

सत्रिगृहस्य हिमांशोरपक्रमांशान् यथादिशं कुर्यात् |
प्रागपरसिद्धिरेवं (चक्रा)द् याम्योत्तरे ज्ञेये || ३ ||

3. Add three *rāśis* to the Moon's longitude and find the degrees of declination of this point. If the declination is north, lay the degrees north of E′, if south, south of E′. This is the east-point with respect to the ecliptic (E″ in the figure.) Draw the straight line through the centre, E″ OW″ . E″ − W″ is the ecliptic east-west. By means of circles, (i.e. by drawing the perpendicular bisector), get the ecliptic north-south, viz. N″ − S″.

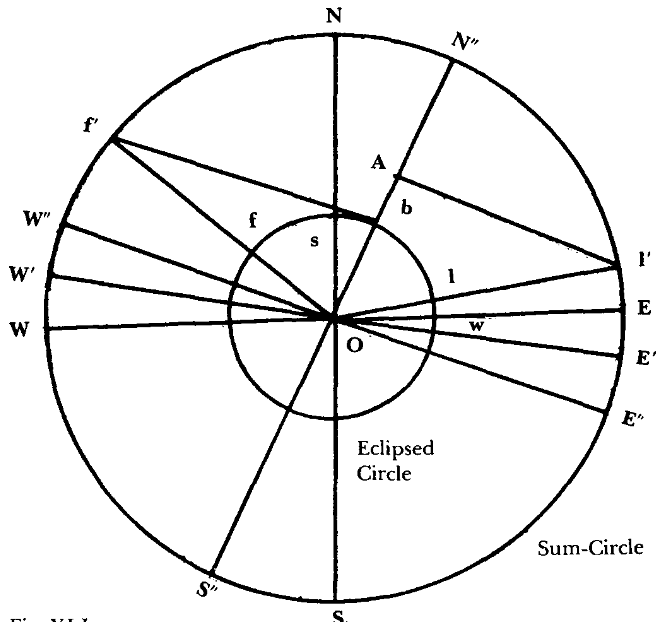


Fig. XI.I

For illustration, we shall represent in the figure the lunar eclipse worked out in the examples of chap. X. The angular diameters of the Moon and the Shadow got there are 31′.8 and 76′.9. The Moon's lat. at first and last contacts are, respectively, 19′.35 and 27′.65, both north. The first and second half durations are *nā.* 4-14 and *nā.* 3-54, respectively. Let us assume that at T, the hour angle, is 10 *nāḍis,* i.e. 60°, west and the latitude of the observer is 10° 24′ (N). The Moon's longitude has already been given as *rā.4-0-0.*

(i) The half sum of the angular diameters = 108′. 7 ÷ 2 = 54′.35. This is to be converted into digits using the formula of verse 6, below, and used as the radius of the sum-circle. It is, 54.35 ÷ (3 − 10/15) = 23.3 digits. According to the scale in the figure, 1 unit = 10 digits, this is 2″.33.

3b. B.°मांशात् द्यथा
c. A.सिधिरेवं C.मत्स्याद्; D.बकाद्
d. A.B.वकाद् A.याम्यान्तरे; B.याम्योत्तर D.ज्ञेये[च]

(ii) The semi-diameter of the eclipsed body, (here the Moon), is 31′.8 ÷ 2 = 15′.9 = 15 ÷ (3 − 10/15) in digits, = 6.8. According to the scale used, this is represented as, "0.7, radius of eclipsed circle.

(iii) For the hour angle of 60°, the tabular versine = 60′, and tabular sine latitude of observer is 21′ 40″. From these, the tabular sine of the angle of deflection caused by lat. = 60′ × 21′ 40″ ÷ 120′ = 10′ 50″. The angle of deflection = 5° 11′, south of the east point, since the hour angle is west. This is angle, EOE′, and E′ − W′ is the equatorial east-west.

(iv) Longitude of Moon + *rā.* 3-0-0 = *rā.* 7-0-0. The declination of this point is 11° 44′, south, which is the southward defection from E′, represented as angle E′ O E″. E″ − W″ drawn is therefore the east-west of the ecliptic.

(v) The perpendicular bisector of this, N″ S″, is the north-south direction with respect to the ecliptic.

The explanation that may be required here has all been given in the context of the *Vāsiṣṭha* lunar eclipse (chap. VI), in connection with the graphical representation there. It has also been shown that the methods for the deflections are rough, and that using the versine for latitudinal deflection, as done by the early astronomers instead of the sine, is incorrect. It is also to be noted that the way of giving the representation by our author here is different from those of others, as also very limited in its scope.

The readings: We have emended certain readings according to the idea intended to be conveyed. In the first stanza, the reading *diśam,* is all right, and emending it into *diśaḥ* by TS and NP is unnecessary, since the singular form can give the meaning of the intended plural number, according to the *śāstra.* Again, in verse 3, it is enough if *vakāt* is read as *'cakrāt,'* and there is no need to emend it into *matsyāt,* as TS have done. NP emend it as *bakāt,* give it the meaning 'fish' (!) and add a syllable *'ca'* at the end of the line to make up the metre. The intended meaning, viz. 'perpendicular bisector', can be got from *cakrāt,* following the ms lettering and meaning 'by means of circles', for it is by the intersection of circles that the fish-figure itself is got.

[स्पर्शमोक्षबिंद्वङ्कनम्]

दिग्व्यत्ययेन शशिनो विक्षेपा(न्ता)द्दिगन्त(गं) सूत्रम् |
स्पर्शो द्वितीयवृत्ते तस्मादन्यत् (स्पृशे)न्मध्यम् || ४ ||
तत्सम्पाते स्पर्शो मोक्षोऽप्येवं विपर्ययात् साध्यः |
तात्कालिकात् स्व(बु)द्धया मो(क्षे) दिक् संविधातव्या || ५ ||

Marking of points of contact etc.

4. In the case of the lunar eclipse, mark on the 'eclipsed body circle' the direction points in reverse of the points on the sum-circle in the fig. s e n w for N W S E. On the N″ − S″ line, mark the Moon's latitude at first contact (converted into digits,) according to its direction, (point L in the figure,) and take it (westward) to the sum-circle, (to f′ in the fig.) Join this point on the semi-circle and the centre with a straight line.

5. Where this line cuts the eclipsed circle (f in the fig.) is the point of first contact. To get the point of last contact also, similar work should be done, using he Moon's latitude at the time of last contact, marking it on N″ − S″ line, and drawing the line to the sum-circle in the opposite direction, (i.e. not west ward but earst-ward). (The point of last contact got is l in the fig.)

Note: Since the directions are asked to be marked reversed in the case of the Moon eclipsed, we understand that they have to be marked as they are when the Sun is the eclipsed body. The first part of the instructions can be understood to be intended for first contact, since the second part is expressly stated to be for last contact. Since the Moon's latitude of the moment of last contact is asked to be used to find that point, we infer that the latitude of the moment of first contact is to be used to find the first point. The drawing of lines to the westward rim and eastward rim of the sum-circle can be inferred from the known directions of first and last contacts, keeping in mind that they are marked reversed on the Moon-circle.

Thus, the following is the work to be done:

(i) In the case of the lunar eclipse alone, mark the directions reversed, on its rim. Take the Moon's latitude at the time of that particular contact whose point is to be found. Measure it along N″ − S″ according to its own direction, and mark the point. (In the solar eclipse the latitude is to be parallax-corrected.) (In the fig. these points are L, A, for first and last contacts, respectively.)

(ii) From this point, draw a line parallel to E″ − Ẇ″, westward or eastward, respectively, for first or last contact, to meet the rim of the sum-circle, (as in fig, Lf′ or Al′.)

(iii) Draw f′O or 1′O to intersect the rim of the eclipsed at f or l. These are the points of first and last contacts.

For example, in the fig, we shall find these:

(i) The points of contat for the lunar eclipse is wanted. Therefore N W S E are reversed as s e n w. The latitudes are 19′.35 N, and 27′.65 N, Converted into digits, these are 8.3 and 11.9. According to scale, in the fig., these are 0″.8 and 1″.2. Measuring along ON″, the points marked are L, and A, respectively.

(ii) The westward parallel for first contact drawn is Lf′, and the eastward parallel for last contact drawn is Al′.

(iii) Joining f′ and l′ with O, the point of first contact got is f, and the point of last contact got is 1. Thus, we find from the figure that the first contact is very near the southeast point of the Moon's rim, and the last contact is a little to the south of its west point.

4b. A.B.विक्षेपान्तद्; C.विक्षेपं तत्; D.विक्षेपस्तत्
A.C.D.दिगन्तकं; B.दिगतकं
c. A.B.स्पृश; C.स्पृशद्; D.स्पृशेद्
C.द्वितीये वृत्ते; D.द्वितीयं वृत्तं
d. A.॰दन्यश्येन्मध्यं || B.॰दन्यच्चेन्मध्यान्तसंपाते ||४ ||
Really त संपाते belongs to verse 5.
C.॰दन्यं स्पृशेन्मध्यम्; D.॰दन्यं [लि] खेन्मघात्
5b. A.मोक्ष्येप्येवं B.विपर्ययशोध्यः
c. A.स्वकृध्या; B.स्वकृतवृध्या D.स्वकृत्या
d. A.B.मोक्षत्वा दिक्; C.मोक्षत्वाद् दिक्; D.मोक्षाद्दिक्
A2.विघालव्या

The explanation of all this has already been given. The author does not go beyond this in his graphical representation. The corrections of the text to agree with the ideas intended to be conveyed, are easily understood.

[कलानामङ्गुलीकरणम्]

लिप्ताद्वयेन हरिजे त्रयेण (मेषूरणे) ऽङ्गुलं भवति ।
अनुपातोऽन्तर [सं] स्थे कर्तव्यो दृष्टियुक्तार्थम् ॥ ६ ॥

Conversion of minutes into angles

6. So that the graphical representation may appear as the eclipse is seen actually, the minutes of arc are to be converted into digits, at 2′ per digit when the Moon is near the horizon, and at 3′ per digit when it is on the tenth sign, i.e. meridian, and proportionately in between.

The proportion is as follows: In the fifteen *nāḍikās* (roughly) when the Moon rises from the horizon to the meridian, or falls from the meridian to the horizon, there is an increase of one minute of arc from 2′ to 3′, or decrease of one minute of arc from 3′ to 2′; what is it at a given time? The number of minutes thus obtained is to be represented by one digit in the graphical representation. At this rate the minutes of latitude etc. are to be converted into digits. In the example, for the hour angle of ten *nāḍis*, we have the rate per digit, (3 − 10/15) = 2 1/3 minutes, i.e. three digits per seven minutes.

The following is the explanation of the conversion formula: The Sun and the Moon appear to be larger at the horizon, and to become smaller and smaller as they proceed to the meridian and near the zenith. This is an optical illusion, and really the size is practically the same, as can be proved by measurement, taking photographs etc. We shall not explain the phenomenon here as it is outside the pale of astronomy proper. But we must mention that the explanation given in some works like the *Siddhāntaśekhara* in wrong.

Our author has taken that the magnification at the horizon is one and a half times that at the zenith, (practically the meridian in our latitudes) and the increase in size is proportionate to the hour angle, though this may not be strictly true. He also thinks that the orbs, which are nearly 32′, appear to be about 11 digits near the zenith, and about 16 digits at the horizon. Hence his rule, two minutes per digit at the horizon, and three on the meridian. With the possibility of different people giving the actual estimate of size differently, what the author says must be taken as only approximate. Therefore no harm will ensue by taking the meridian for the zenith, or by taking the mean value of the maximum hour angle, viz., 15 *nāḍikas*, in finding the proportion, especially in our latitudes.

6b. A. सेषूरणंगुल
c. A. तरःस्थे; B. तरस्थे
d. B. भुक्तार्थिः

[इति पञ्चसिद्धान्तिकायां वराहमिहिरविरचितायां
अनुवर्णनं नाम एकादशोऽध्यायः][1]

1. Col. A.B. अवर्णनात्येकादशोध्यायः । C. इत्यनुवर्णनं नामैकादशोध्यायः । D. अ [नु] वर्णनमेकादशोध्यायः ।

Thus ends Chapter Eleven entitled 'Eclipse Diagram' in the Pañcasiddhāntikā composed by Varāhamihira

Chapter Twelve

PAITĀMAHA SIDDHANTA

द्वादशोऽध्यायः
पैतामहसिद्धान्तः

Introduction

In this chapter *Varāhamihira* deals with the *Paitāmaha siddhānta,* the other four having already been dealt with. As an astronomical work the *Paitāmaha* is of very little value, as the author has remarked in his Introduction, "*the tithis* of the other two, (meaning the *Vāsiṣṭha* and the *Paitāmaha*), are far from correct." Since this *siddhānta* gives only the mean Sun and Moon, and therefrom the mean *tithis,* it cannot satisfy the requirements of the *Dharmaśāstras.* But it is historically important as a system that immediately followed the *Vedāṅga Jyotiṣa.* We shall explain at the end of the chapter how this could have subserved religious purposes in ancient times, and what merits it possesses as the basis of a civil calendar.

[अहर्गणः]

रविशशिनोः पञ्च युगं वर्षाणि पितामहोपदिष्टानि ।
अधिमासास्त्रिंशद्भिर्मासैरवमो द्विषष्ट्याऽह्नाम् ॥ १ ॥
(द्व्यू)नं शकेन्द्रकालं पञ्चभिरुद्धृत्य शेषवर्षाणाम् ।
द्युगणं माघसिताद्यं कुर्याद्यु[गभानि] वह्न्युदयात् ॥ २ ॥

Days from Epoch

1. The *Siddhānta* of *Paitāmaha* teaches that the luni-solar *yuga* is five years. After every thirty synodic months there is an intercalary month, and there is an omitted day for every 62 lunar days or *tithis.*

2. Subtract two from the years of the elapsed Śaka era, and divide out the remaining year by five. The 'days from epoch' are to be calculated for the remaining years etc., the first day being the *śuklapratipad* of the month of Māgha. The *nakṣastras* of the Sun and the Moon, calculated by using the days, are for sunrise.

1-2 Quoted by Utpala on *BS* 8.22

1c. D.मासः
d. A.मासैरवमस्त्रिपद्याप्तुं |; B.मासिरवमस्त्रिषष्ट्यार्का (B2.3. षष्ट्यंका)
C. द्विषष्ट्या तु.

2a. A.B.द्युनं; U.द्यूनं
b. A.पञ्चविगुधृत्य; B.पञ्चविगुहृत्य A1.वर्षाणं
c. A.B.°माद्यसिताद्यं
d. A.B.C.D.कुर्याद्यु (B.द्भ्यु; C.D.द् द्यु) गणं
A.C.D.तदहन्युदयात्; B.तदद्भैदयात्; U.तद्वह्न्युदयात्

The period after which the Sun, Moon, and the planets all meet again at the first point of the zodiac is commonly called the *yuga,* meaning "the period of union." Here this is meant for the Sun and Moon alone, and this *Siddhānta* takes it to be five years, approximately, with a view to convenience. In the same way, the statements that there is an intercalary month after every thirty months, and an omitted day for every 62 lunar days, are approximate, and rounded off for convenience. The first *tithi* of the light fortnight of Māgha begins the *yuga,* and the year and the day begins with sunrise.

The author has not mentioned the number of intercalary months or days in the *yuga,* nor has he given how to get the 'days from epoch', expecting the readers to be experienced enough, by now, to know it for themselves. He has indicated it in I.16, and we have explained it under I.14-17. The only thing that is necessary is to know the years of the beginnings of the *yuga,* and this has been given here as two years after the śaka epoch, and every five years thereafter.

We shall first compute the number of the intercalary months etc in the *Yuga.* The number of years in the *yuga* is 5, given. The solar months are $5 \times 12 = 60$. The intercalary months are, $60/30 = 2$. The lunar or synodic months are, $60 + 2 = 62$. The lunar days or *tithis* are $62 \times 30 = 1860$. The omitted lunar days are, $1860 \div 62 = 30$. The (civil) days are, $1860 - 30 = 1830$. The Moon's revolutions are, the Sun's revolutions + the synodic months $= 5 + 62 = 67$. The *Vyatīpātas* are, solar revolutions + lunar revolutions $= 5 + 67 = 72$. The number of days in the solar year is, $1830 \div 5 = 366$. The days per *ayana* are $366 \div 2 = 183$. This is enough for our purpose.

To get the 'days':-

(i) (Elapsed śaka years — 2) ÷ 5. Take the remainder alone.

(ii) The solar months gone = (i) × 12 + elapsed months from Māgha.

(iii) The intercalary months = (ii) ÷ 30. Take the quotient alone.

(iv) The lunar months gone = (ii) + (iii).

(v) The lunar days gone = (iv) × 30 + *tithis* gone in current month.

(vi) Omitted days = (v) ÷ 62. Take the quotient alone.

(vii) The days from epoch are, (v) − (vi).

The *tithis* gone, used in (v) are actual elapsed *tithis,* and not those increased by one (according to verse 4. of this chapter,) for calendrical purposes. If the latter is used, subtract the calendrical elapsed *tithi* from the remainder got in (vi). If this is greater than 46, lessen the days from epoch by one to get the correct days. The reason for this will be explained while dealing with verse 4, following. Further, since there can be no fraction of intercalary month or *avama* at the beginning of a *yuga* carried over from a previous *yuga,* there is no *kṣepa* for these, in the computation rules. As for the explanation of these rules it has already been given in chap.I, when dealing with the rules for days from epoch according to the *Romaka.* The names of the five years, (not given in the text,) are: *Saṁvatsara, Parivatsara, Idāvatsara, Anuvatsara,* and *Idvatsara.* In certain Vedic *śākhās,* there is a slight variation in some names.

As for the reading of the text, we have corrected *dyūnam,* into *dvyūnam,* since the former is meaningless in the context.

Example 1. Compute the 'days from epoch' according in the Paitāmaha, for the sunrise of calendrical date eleventh of the light fortnight of Kārttika, in the elapsed Śaka year 426.

(i) $(426 - 2) \div 5 = 424 \div 5$. Here the remainder is 4, the years gone, in the current *yuga*. The fifth, *Idvatsara* is current.
(ii) Counting from Māgha, 9 months have elapsed before (*Kārttika*), in the current year. ∴ the solar months gone $= 4 \times 12 + 9 = 57$.
(iii) Intercalary months = 57/30, = 1 27/30 (quotient = 1)
(iv) Lunar months gone $= 57 + 1 = 58$.
(v) The calendrical *tithis* gone in the month are 10. ∴ the total *tithis* gone $= 58 \times 30 + 10 = 1750$.
(vi) Omitted *tithis* $= 1750 \div 62 =$ 28 14/62. (The quotient, 28 are the omitted *tithis*). Since the remainder, 14, *minus* 10, leaves 4, which is not greater than 46, the calendrical *tithi* itself is the *tithi*.
(vii) Days from epoch $= 1750 - 28 = 1722$.

[तिथिनक्षत्रादिः]

सैक(त्वं)शे द्युगणे तिथिर्भमार्कं नवाहते'ऽक्ष्यकैः' |
'दिग्रस'भागैः सप्तभिरूनं शशिभं धनिष्ठाद्यम् || ३ ||

Tithi, Nakṣatra etc.

3. Add to the 'days' a sixty-first part of itself. The total *tithis* are got, (which, divided out by thirty, leaves the *tithis* in the month). Multiply the 'days' by 9, and divide by 122. The total *nakṣatras* are got, (which, divided out by 27, gives its actual *nakṣatra*, reckoned from *Śraviṣṭhā*). Multiply the 'days' by 7 and divide by 610. Subtract this from the 'days'. The remainder are the total *nakṣatras* of the Moon, (which, divided out by 27 and the remainder counted from *Śraviṣṭhā*, is the Moon's *nakṣatra*).

The following is to be done:-

(i) *Tithi* = 'days' + 'days' ÷ 61. (This, divided out by 30, and the remainder counted from *śukla-pratipad*, is the *tithi* proper).
(ii) Sun's *nakṣatra* = 'days' × 9 ÷ 122. (This, divided out by 27 and the remainder counted from *Śraviṣṭhā*, is the Sun's *nakṣatra*).
(iii) Moon's *nakṣatra* = 'days' − 'days' × 7 ÷ 610. (This, divided out by 27 and the remainder counted from *Śraviṣṭhā*, is the Moon's *nakṣatra*).

Example 2. For the date of Ex. 1, find the tithi etc.

The 'days' got there are 1722.

(i) *Tithi* $= 1722 + 1722 \div 61 = 1722 +$ 28 14/61 = 1750 14/61. Divided out by 30, the remainder is 10 14/61. ∴ the 10th *Tithi* of the light fortnight is gone, and 14/61 of Ekādaśi has gone at sunrise.

3. Quoted by Utpala on *BS* 8.22.

3a. A.B. सैकत्र्यंशत्वं (B. न्वं) चेद्युगणे; C. सैकषष्टयंशे द्युगणे; D. सैकषडंशे द्युगणे; U. सैकत्रिंशे

b. A.B. भमार्कनचा (B. वा) हस्नेष्टकैः (B. हसेष्ठकैः); U. °नवाहतो°

c. A.B. दिग्रह; D. भक्तैः

d. A. नूनं A. धनिष्टाद्यं; B2. धनीष्ठाधं

(ii) Sun's *nakṣatra* = 1722 × 9 ÷ 122 = 127 4/122. Dividing out by 27, the remainder is 194/122. Counting from *Dhaniṣṭhā*, Citrā is gone, and the Sun is at 4/122 of Svāti.
(iii) Moon's *nakṣatra* = 1722 − 1722 × 7 ÷ 610 = 1722 − 19464/610 = 1702 146/610. Divided out by 27, the remainder is 1 146/610. Śraviṣṭhā is gone, and the Moon is at 146/610 of Śatabhiṣaj. It is to be noted, that two of these being known, the third can be counted from them.

The following is the explanation of the rules: Under verses 1−2, the number of days in the *yuga* etc. have been got. Using them, the total *tithis* are got by the proportion, 1830: 'days' :: 1860: *Tithis*. ∴ *Tithis* = 1860 × 'days' ÷ 1830 = 'days' × 62 ÷ 61 = 'days' (1 + 1/61) = 'days' + 'days' ÷ 61.

Next, since there are five solar years in the *yuga*, there are 5 × 27 = 135 solar *nakṣatras*. We have the proportion, 1830: 'days' :: 135: total Sun's *nakṣatra*. ∴ Sun's *nakṣatra* = 135 × 'days' ÷ 1830 ='days' × 9 ÷ 122.

Next, since there are 67 revolutions of the Moon in the *yuga*, there are 67 × 27 = 1809 *nakṣatras*. So, we have the proportion, 1830: 'days' :: 1809: Moon's *nakṣatras*. ∴ Total Moon's *nakṣatras*. = 1809 × 'days' ÷ 1830 = 'days' × 603 ÷ 610 = days (1 − 7/610) = 'days' − 'days' × 7 ÷ 610.

While the mss. readings *tryaṁśatvaṁce* etc. are corrupt, Bhaṭṭotpala's reading *saikatriṁśe* itself is wrong, since it contradicts facts, and we have emended it into *saikartvaṁśe*. TS have corrected is as *saikaṣaṣṭyaṃśe gaṇe* which is not proper since the correction does not follow the letters of the text. NP emends it as *saikaṣaḍaṃśe* for the number 61 that is required, but generally the said number is not found to be formed thus.

[तिथिः व्यतिपातश्च]

प्रागर्धे पर्व यदा तदो(त्त)राऽतोऽन्यथा तिथिः पूर्वा |
'अर्क'घ्ने (व्यति)पाता द्युगणे 'पञ्चाम्बरहुताशै': || ४ ||

Vyatipāta

4. If the moment of full or new moon falls before noon, the second of the two *tithis* connected with the day is the (civil) *tithi* for the day, otherwise the first. Multiply the 'days' by 12 and divide by 305. The *Vyatīpātas* are got.

The *tithi* of this *Siddhānta* is mean *tithi*. Since this is less than the day, each day has parts of two *tithis* connected with it, and we have to fix one of them as the date of the particular day. It is this that is done by the first half of the stanza, it seems. If others like the *Śrāddha-tithi* are meant to be fixed here, they would be mentioned by name. The mere word *tithi* without an attribute must mean only the date. Agreeing that the date is meant to be fixed here, is it the date of the full or new Moon alone that is fixed here, or that of any day? From the word *parva* used, one may think it is only the former that is sought to be fixed. But this cannot be, since fixing the date of one particular day among so many is practically useless. If it is argued that the fixing of the day as *parva* or *pratipad* is useful to

4b. A. तदोतरत्तोन्यथा; B1.3. तदा तए सोन्यथा; B2. तदा तरों तोन्यथा
c. AB. व्यापिपाता; D. व्यतिपातो
d. A. द्यगणे
A. पंचावरहु.ाशैः; B. पञ्चाम्बरं हूतांशैः (B2. द्तां शैः)

determine whether the *anvādhāna* or the *iṣṭi* is to be performed on that day, then the general term, *tithi*, need not have been used, and it would have been easier to mention the thing. Further this is a matter for the Dharmaśāstras to deal with, not for an astronomical work. Therefore, by fixing the date of the *parva*, the author means to fix all the subsequent dates following, upto the next *parva*, and make them convenient for civil use. If the dates are consecutive, one for each day, it will be convenient for civil reckoning. If there is a jump, omitting one date in the middle (*tithikṣaya*), it is plainly inconvenient. The instruction in the verse secures that the dates follow without omission in the middle of the fortnight. For, if the moment of full or new moon is after noon, there will be no omitted *tithi* in the fortnight following, and the corresponding dates will follow one after another each day, beginning from *prathamā*, next day. But, if the moment of full or new moon is before noon, then there will be an omitted *tithi* in the fortnight following, since the remainder in getting the omitted days will be greater than 46, increasing by one each day. Therefore, if now the day of full or new moon itself is reckoned as the first date of the fortnight, then the reckoning can be continued to the end of the fortnight without omission. It is bearing in mind this idea implied by the text, that we made a distinction between the astronomical and the civil date, in giving the computation of the 'days from epoch'. The *Siddhānta* is only repeating here the idea of the *Vedāṅga Jyotiṣa* in:

dyu heyam parva cet pāde pādas triṃśattu saikikā |

the term *pāde* (meaning 'quarter day') corresponding to the term *ardhe* in our text. The thirty-one parts mentioned form the measure of the *pāda*, in units of 1/124 parts of a day.

We have explained the *vyatipāta* in detail, in our commentary on III.20. We must remember here two things that we said there:

(1) *Vyatipāta* occurs when the Sun and the Moon have the same declination, (both north or both south), and when one is moving northward while the other is moving southward.

(2) If the Sun, Moon, and declination are all mean, as here, and if the first point is at the solstice, as here, mid-*vyatipāta-yoga* must fall when the Sun + Moon equals 12 *rāśis*. In the *yuga*, (of 1830 days) there are 5 + 67 = 72 such *yogas*, i.e., *vyatipātas*. Therefore, for given 'days', there are, 72 × 'days' ÷ 1830 = 12 × 'days' ÷ 305, *vyatipātas*, as given here. The quotient obtained are the *vyatipātas* gone. But this knowledge is practically useless, and we must take it that the *Siddhānta* intends here to give when the *vyatipāta* occurs, a time extremely propitious for gifts, *japa*, *homa*, etc. This can be found easily from the remainder. Divide this by 12. The result is days etc. gone from the last *vyatipāta*. Subtracting the remainder from 305 and dividing by 12, we get the days to the middle of the next *vyatipāta*. If the remainder is zero or nearly so, it is clear that the *vyatipāta* is on.

Example 3(a). Given the 'days' 1697, what is the tithi for that day, and the subsequent days, upto the end of the fortnight?

The *tithis* gone = 1697 + 1697 ÷ 61 = 1697 + 27 50/61 = 1724 50/61. Dividing out by 30, the remainder is 14 50/61, i.e. 50/61 part of *pūrṇimā* has gone, and 11/61 part remains. Since the *tithi* is equal to 61/62 day, 11/61 *tithi* equals, 11/61 × 61/62 = 11/62 day. The full Moon ends at 11/62 day, i.e. before noon. Therefore that day itself is *Prathamā*, (not *Pūrṇimā*). (The same conclusion follows from the remainder of the omitted day, 51, in this case, (minus zero, for the civil day gone,) being greater than 46. After this, for ten days, the *tithis* are from the second to the eleventh, for civil purposes, though at sunrise the *tithis* are from the first to the tenth, the eleventh being the omitted *tithi*. On the next day the *tithi* at sunrise is the twelfth, as also the civil *tithi*, and so on.

Example 3(b). Given the 'days' 1722, find when the vyatipāta falls.

1722 × 12 ÷ 305 = 67 229/305, i.e. 67 *vyatipātas* have gone, from the beginning of the *yuga*. The remainder is 229. Dividing by 12, we get 19-5, days etc. gone from last *vyatipāta.* Subtracting from 305, and dividing by 12, we get days etc. 6-20, to go for the middle of the next *vyatipāta,* i.e, it will be falling at 20 *nāḍis* on *Kārttika Kṛṣṇa-dvitīyā.*

The correction of the reading here is easy to understand. Of TS, the latter says some farfetched thing as the meaning of the first part of this verse, which seems meaningless to me, and the former without saying anything himself, refers us to the Sanskrit commentary, evidently not understanding it himself. In explaining the *Vyatipāta,* their use of the one forming the seventeenth of the series Viṣkambha etc., can serve no purpose in the present case. The same confusion is seen also in NP (see Pt II.p.82). We have already shown that the series itself did not exist at the period of Varāhamihira.

[अहर्मानम्]

(गतमयनादुत्तरतो) (द्यूनां) (गन्तव्य)मपि च याम्यस्य |
(द्विघ्नं) 'शशिरस'भक्तं द्वादश(सहितं) दिवसमानम् || ५ ||

Duration of a day

5. Take the days gone in the *Uttarāyaṇa,* i.e. the northward course of the Sun, and the days to go in the *Dakṣiṇāyana,* i.e. the southward course. Multiply by two, divide by 61, and add 12. The duration of the day time (*in muhūrtas*) is got.

Though the text is very corrupt here, since we know that the duration of daytime is given here, and that as mentioned in the *Vedāṅga Jyotiṣa,* many words occurring in that work being recognisable here, we have succeeded in reconstructing the verse using the letters found in the text, though not to our entire satisfaction. But there is no doubt about the idea intended to be conveyed, viz. that of *VJ* (verse 22 of the *Ṛgveda* version and verse 40 of the *Yajurveda* version). But TS and NP, in order to retain the expression *dvādaśahīnam,* read into the text many impossible things and make several emendations not caring even for the metre.

The rule given is thus explained: According to this *Siddhānta* the shortest day is 12 *muhūrtas,* at the end of the southward course and the beginning of the northward at Winter solstice, and the longest is 18 *muhūrtas* at the end of the northward course and the beginning of the southward, at Summer solstice. Each course has 183 days, and the increase or decrease of daytime is considered uniform. Therefore, since there is an increase of 6 *muhūrtas* from 12 in the 183 days of the northward course, the increase for a desired number of days (counted from the beginning) is: days gone × 6 ÷ 183 = days gone × 2 ÷ 61. So, the duration is 12 + days gone × 2 ÷ 61. Taking the southward course, it is 12 *muhūrtas* at the end, proportionately greater, the earlier is the day, the increase being 6 in 183 days, at the beginning of the course. Therefore, during the southward course, the duration is 12 + the days to go in the course × 2 ÷ 61. It is to be noted that the author has not said

5a. A.B. धृतिरनयाद्युत्तरयो (B1.3.॰तरयो); C.द्व्यग्निगेषूत्तरतः; D. [सत्रि] धृति [च] रणध्यु [मु] त्तरगे
C. स्वमितमेष्य दिनमपि याम्यायनस्य
D. त्वगतद्युमपि च याम्यस्थे

b. A. स्वमृणं तद्यमपि च याम्यस्य; B.सू (B3.ख) मृणं गतद्यमपि च याम्यास्य;

c. A.द्विग्रं; B.द्विग्रं B.मक्तं

d. A.B.C.D.द्वादशहीनं

when the northward course begins, and when the southward one. (Perhaps he has said that in this verse, and the corruption of the text has masked it.) When the Sun enters Śraviṣṭhā its northward course begins, and when it is at the middle of Āśleṣā, its southward course begins, or the first half of the year is the northward course, and the second half, the southward one. It can also be inferred from the rule for *vyatipāta*.

Example 4. Given the 'days' 1722, find the daytime for the day following.

1722 ÷ 366 = 4 258/366. Four years have gone, and 258 days in the fifth. The 183 days of the northward course have gone, and 75 days have elapsed in the southward course. The days to go = 183 − 75 = 108. The duration of daytime in *muhūrtas* = 12 + 108 × 2 ÷ 61 = 12 + 3 33/61 = 15 33/61.

To conclude, it has been said in the introduction to this chapter that the Sun, Moon etc. of this *Siddhānta* are only mean, not true. Some think it is even worse than this, which we must investigate now. We have seen that, according to this *Siddhānta,* there are 366 days in the year, 5 years or 1830 days constitute the *yuga,* and there are 62 synodic months in it. But actually there are about 365 $^{1/4}$ days in the year, and also 62 synodic months take 1830.8965 days. Therefore, instead of being at the zero point of Śraviṣṭhā at the beginning of each *yuga,* the Sun will be advancing by about three degrees per *yuga.* The synodic month being not completed, it will be really only Caturdaśī then, and at the end of every *yuga,* the *tithi* will be preceding by about one per *yuga.* This is common to both this *Siddhānta* and the *Vedāṅga Jyotiṣa.* But accumulation of this error is prevented by tying the *Yuga* to the correct Śaka year, by the instruction to use the Śaka year for finding the year of the *yuga.* (This is of the same nature as tying the lunar year to the solar.) It may be said, in passing, that at the period when the *VJ* was followed, actual observation was used to find out when a correction was wanted and the same made by simply omitting an intercalation, for which, it is possible, they could even have discovered a formula in the long run. We have made this clear in our Notes to the *VJ,* (Indian National Se. Ae., New Delhi, 1985) and the during the Seminar on Indian Calendar held by the Institute of Traditional Cultures, University of Madras. (Bulletin of the Institute of Traditional Cultures, Madras, 1968, Part I, page 60.) When thus the accumulation of error is taken care of, giving 366 days to the year is extremely convenient for civil, calendrical, and even religious purposes, since it makes calculations easy in the same way as we, even now, take the year to have 365 days, and the months 31 etc. days. We get 183 days for each *ayana,* 122 days for each *cātarmāsya,* and 61 days for each *ṛtu, all in whole numbers.* There are 61 *sāvana* months in the *yuga.* Even the *saura* month has 30 days and a half, a fraction easy to work with. Further, the fortnight or *pakṣa* was the unit used then in the place of the modern week. We have shown, in our Notes on verses 2 and 4 above, how it was secured that the dates follow consecutively in the *pakṣa,* a factor so essential for a civil calendar. The approximateness of the *tithis* etc. being mean, is of course there, but this is only an advantage in civil reckoning. As for religious purposes, the true *tithis* etc. required for rites like *darśa-pūrṇa-māsa* were guessed from earlier observations, as we have said, and there are several indications in the Vedas that such was the case. The *abhyudayeṣṭi,* enjoined to be performed if the Moon is observable in the east between the *anvādhāna* on the previous day and the *iṣṭi* on the next day, is one such indication, for, if the visibility had been properly calculated from the true Sun and Moon, using *dṛkkarma* etc. there would be no need for *abhyudayeṣṭi* at all.

[इति पञ्चसिद्धान्तिकायां वराहमिहिरविरचितायां पैतामहसिद्धान्तो नाम द्वादशोऽध्यायः]

Thus ends Chapter Twelve entitled 'Paitāmaha Siddhānta' in the Pañcasiddhāntikā composed by Varāhamihira

Col. A.D. इति (A om इति) पैतामहसिद्धान्ते द्वादशोध्यायः B. इति पितामहसिद्धान्ते द्वादशोऽध्यायः C. इति पैतामहसिद्धान्तो नाम द्वादशोऽध्यायः

Chapter Thirteen

SITUATION OF THE EARTH: COSMOGONY

त्रयोदशोऽध्यायः
त्रैलोक्यसंस्थानम्

[भुवः संस्थानम्]

पञ्चमहाभूतमयस्तारागणपञ्जरे महीगोलः ।
खेऽयस्कान्तास्थो लोह इवाऽवस्थितो वृत्तः ॥ १ ॥

तरुनगनगरारामसरित्समुद्रादिभिश्चितः सर्वः ।
विबुधनिलयः सुमेरुस्तन्मध्येऽधःस्थिता दैत्याः ॥ २ ॥

सलिलतटासन्नानां अवाङ्मुखी दृश्यते यथा छाया ।
तद्वद् गतिरसुराणां मन्यन्ते तेऽप्यधो विबुधान् ॥ ३ ॥

गगनमुपैति शिखिशिखा क्षिप्तमपि क्षितिमुपैति गुरु किंचित् ।
यद्वदिह मानवानां असुराणां तद्वद्देवाऽधः ॥ ४ ॥

Situation of the earth

1. The spherical earth which is constituted of the five elements, stands poised in the region of space, marked by the host of stars forming a cage as it were.

Note: The earth is called so because of the five elements constituting it, it is predominantly earthy.

2. The whole earth-surface is spotted by trees, mountains, cities, rivers, oceans, etc. The Meru mountain, (forming the North pole), is the abode of Devas. The Asuras, (Demons), are down below (i.e. at the South pole.)

1-4. Quoted by Utpala on *BS* 2.55; by Sūryadeva and Nīlakaṇṭha on *ABh.* Gola. 6;2-3 by Pṛthūdaka on *BrSS* 21.3; 3 by Sūryadeva on *ABh.* Gola 12.

1a. A.पंजरे

c. A.खेयस्कांतोंतस्थो; C.D.खेयस्कान्तान्तस्थो

d. A1.वृतः

2a. A2.तनुनग. A1.नगरनरामरसरित्; B.नगरननरामरसरित्

b. B2.°भिश्चितः

c. A.°धस्थिता

3. Just as the reflection of the objects on the bund of a water course is upside-down, so the Asuras are, (with respect to the Devas). The Asuras too consider the Devas to be upside-down.

4. Just as the flame of the fire, observed by men here, flares upwards, and anything thrown up falls down towards the earth, the same upward flaring of the flame, and the down-ward falling of a heavy object is experienced by the Asuras, (at the anti-podal region).

[भूभ्रमणम्]

मेरोः सममुपरि वियत्यक्षो व्योमस्थितो ध्रुवो(ऽधोऽ)न्यः |
तत्र निबद्धो मरुता प्रवहेन भ्राम्यते भगणः || ५ ||
भ्रमति भ्रमिस्थितेव क्षितिरित्यपरे वदन्ति नोडुगणः |
यद्येवं श्येनाद्याः न खात्पुनः स्वनिलयमुपेयुः || ६ ||

Rotation of the earth

5. The axis of the earth extends right up and right down to the stellar sphere. The stellar sphere, bound by the axis to the earth, rotates by the wind system called *Pravaha*.

Note: Seven wind systems are spoken of by Hindu astronomers. The uppermost, blowing permanently westward in the region of the planets and stars, is the cause of their westward rotation once a day.

6. Others say that the earth rotates on its axis, like an object placed at the hub of a wheel, and not the stars. If so, birds like the eagle flying up into the sky, cannot reach their nests back.

Note. This is what is meant: During the time they are away from the nest, they would have been carried far away by the rotating earth, from the spot of origin of their flight and the birds cannot reach the nest. But they do reach, and so this theory is false.

3a. A.B.तजासंताना (B3.सेताना); C.तटसङ्गताना
b. B1.3.दृशाते
c. A1.तद्वगति; A2.तद्वक्षति; B.तद्वर्क्षगति. B.पंन्यन्ते
A. Hapl. om. रसुराणां [... मसुराणां] त
(in verse 4)
d. B1.2.विबुधानाम्
4a-b. B.शिखाक्षितिमुपैति; D.शिखा [क्षिप्तमपि] क्षिति
c. B.तद्वदिह
5. Quoted by Utpala on *BS* 2,p.56
and by Pṛthūdaka on *BrSS* 21.4: 6-8 quoted by Utpala on *BS* 2,pp.56-57, and 6 c-d quoted by Pṛthūdaka on *BrSS* 21.4.

5a. B.समुपवियत्पक्षो; U.समोपरि. A.वियत्पक्षो
b. U.व्योम्नि स्थितो A.B.ध्रुवो धन्यः
c. A.निबधो A.मतुला; B1.3.महता; B2.मरुता
d. B.द्राहवेन; C.D.U.प्रवहेण
6a. A.भ्रम B.स्थिते च; U.स्थितिरिव
b. A.त्पपरे B1.नोद्धुगणः
c. B.पद्येवं A.शेनाद्या; B.शेनाघा

अन्यच्च भवेद्भूमेरह्ना भ्रमरंहसा ध्वजादीनाम् |
नित्यं पश्चात्प्रेरणमथाऽल्पगा स्यात् कथं भ्रमति || ७ ||

अर्हत्प्रोक्तेऽर्केन्दू द्वौ द्वावेकान्तरौ किल तौ |
यद्येवमर्कसूत्रात् किं ध्रुवचिह्नं भ्रमत्यह्ना || ८ ||

7. Further, on account of the great speed of the rotation of the earth, banners, flags, etc. will always be flown westwards, (just as the cloth of a man running eastwards in still air, is blown westwards). If, to obviate this objection, a very slow rotation is postulated, how does the rotation (once a day), take place at all (i.e. one rotation cannot be completed in one day).

8. Arhat, (the propounder of the Jain religion) has written that there are two Suns and two Moons, each rising alternately. If so, how does the line joining the Sun and the celestial pole goes round exactly once in a day round the pole?

Note. This observation shows that the celestial sphere movers once round in a day and carries with it all heavenly bodies. So the same Sun appears each day after one rotation. Therefore, the postulation of a second Sun is purposeless. The same for the Moon.

[देवासुराणां स्थितिः]

प्रोद्यद्रविरमराणां भ्रमत्यजादौ कुवृत्तगः सव्यम् |
उपरिष्टाल्लङ्कायां प्रतिलोमश्चामरारीणाम् || ९ ||

मिथुनान्ते च कुवृत्तादंशचतुर्विंशतिं विहायोच्चैः |
भ्रमति हि रविरमराणां समोपरिष्टात्तदाऽवन्त्याम् || १० ||

नष्टच्छायाप्येवं छायोदक् तत्प्रभृत्युदक्स्थानाम् |
तद्वद्दक्षिणगानां मध्याह्ने दक्षिणा छाया || ११ ||

मेषवृषमिथुनसंस्थे दिवसोऽर्के कर्कटादिगे रात्रिः |
यैरु(क्तो) विबुधानां मेरुस्थानां नमस्तेभ्यः || १२ ||

येष्वेवोदङ् मेषादिस्थानेषु संनिवृत्तोऽपि |
तेष्वेव कथं दृश्यः पुनर्न दृश्यश्च तत्रस्थः || १३ ||

7a. A.रह्राद्; B.रन्यद्
b. A.B. भ्रमणोद्भ्रमा; D. भ्रमरंहस
c. B.पश्र्चाध्येरण
d. B.मथाज्यगा स्यान्कथं

8a. A.केंन्दु; B.केंदुद्वौ
b. A.B.C.D.U.वेकान्तरोदयौ किल तौ (A-तै)
c. B.मर्कस्तत्र किं
d. B.ध्रुवविन्दुह्नां; U.ध्रुवसूत्रं
A.भवत्पह्ना; B.भवत्यह्नाभ्दुन्हा

Situation of the Gods and Asuras

9. The Sun, situated at the beginning of the sign Meṣa, moves along the horizon in the clockwise direction, as seen by the Devas, at the North pole. As seen at the equator, it moves upwards (along the prime vertical). For the Asuras at the South pole it moves along the horizon, in the anti-clockwise direction.

10. The Sun at the end of the sign Gemini is seen moving (by the Devas) round at an altitude of 24°. On that day, it is seen crossing the zenith at Ujjain.

(*Note.* VM considers that the maximum declination of the Sun is 24°, and the latitude of Ujjain is 24°, which is only approximately correct.)

11. Thus, on that day, at mid-day, there is no shadow cast by the gnomon at Ujjain. North of Ujjain the mid-day shadow is directed north, and for people south of Ujjain the shadow is directed south.

12. Some say, "when the Sun is situated in the three signs Meṣa, Ṛṣabha and Mithuna, it is day-time for the Devas, but when in the signs Karkaṭaka, Siṃha and Kanyā, it is night-time. I salute them, (and wish to be rid of them since they are quite wrong.)

Note. The authors of the Dharmaśāstras, followed by the generality of people, consider that the *uttarāyaṇa,* i.e. the northward course of the Sun from the beginning of Makara to the end of Mithuna is day-time for Devas. Its southward course from the beginning of Karkaṭa to the end of Dhanus is considered their night-time. It is their ignorance that is referred to here.

13. Moving in the same north latitudes when in Karkaṭa, Siṃha and Kanyā, as when in Mithuna, Ṛṣabha and Meṣa, how can the Sun be seen and not seen by the Devas, so that it is day-time (in the first three months,) and night-time (in the next three months).

Note. The mistake of these people lies in thinking that *uttarāyaṇa* is the day-time of the Devas, and *dakṣiṇāyana* is night-time. It is only when the Sun is north of the equator while in the 6 signs Meṣa to Kanyā, it can be seen by the Devas, forming their day-time, and in the 6 other signs, it cannot be seen, and it is night-time.

9-13 Quoted by Utpala on *BS* 2. pp. 57-58, 9 quoted by Pṛthūdaka on *BrSS* 21.6; 12 quoted by Parameśvara on *Abh.* Gola 14.

9a. U.प्रोद्यतरवि
b. A.भ्रमत्पजागो कुव्वृत्तगः; B.भ्रमत्यजागो वृभूवृतगः (B3.नृतगः)
c. B.॰ष्ठाध्यङ्कायां (B3.॰श्पा॰)
d. B.चामराराणाम्
10a. B.॰त्ते तेच A.B.क्रुवृत्ता
b. A1.दशचतुर्थिरातिहायोच्चैः; A2.दंश—र्भि—ति; B.दशचतुर्विशतिहापोच्चैः;
d. A.समोपष्टातदावंत्यां; B.॰त्तदावत्यम्
11a-b. A.छायोदक् च भृत्युस्थाना; B.छायोदक्य भृत्युदस्थानां
c. A.तदक्षिणादेनां; C.D.तद्दक्षिणदे [शा] नां
B. Hapl. om.: स्थानाम् (11b) [........ स्थानाम्, 12d] नम. Scribe oblivious of the omission and numbers the extant verses consecutively and breaks the lines to suit the metre.
12a. A.मियुन संस्थे U.संस्थे दिनं खौ कर्क; Pa.दिन मर्के; Pr.कर्कटादिके
c. A.C.D. U.यैरुक्ता
c-d. Pa.मेरुस्थितदेवतानामिति यैरुक्तं नमस्तेम्यः |
13a. A.C.D.U.मेवद्यादि; B.येषेवो दङ्-मेषाद्यादि
b. A.संनिवृत्तोऽपि (A2.तेपि व तेष्वेव); B.स्थानेषु सन्निवृवृशेपि
c.B1.2.तेष्केव B.दृश्य पुनर्नदस्यश्च

[राशिविभागः योजनमानं च]

दृश्ये चक्रस्यार्धे त्रयः [खमध्यात्तु राशयस्तेषाम् ।]
नवतिस्तानि च खण्डान्युदयात् परिकल्पनीयानि ॥ १४ ॥
एकैकोंऽशो नवभिर्नव भागोनैश्च योजनैर्याति ।
समदक्षिणोत्तराणां प्रत्यक्षं खेऽप्ययं मध्यात् ॥ १५ ॥
एवं च नवत्यंशैरष्टौ दृ(ष्टा)नि योजनशतानि ।
स हि तत्प्रमाणदेशे मध्याह्ने द्रष्टुरुदयो यः ॥ १६ ॥

Signs and Yojanas

14. For the Devas, i.e. at the North pole, where the zenith is the north celestial pole, any visible semi-great-circle passing through the zenith is a meridian on the earth. It is 3 signs distance, i.e. 90°, from the zenith to the horizon. This is to be divided into 90 parts, so that each division is a degree.

Note. These semi-circles are actually the meridians of places having the respective meridians of longitude on the earth. Conventionally, Ujjain longitude is the zero longitude, like Greenwich in modern astronomy.

15. These degree-divisions in the sky are the zeniths of corresponding degrees of latitudes on the earth along any meridian, and the distance between each degree of latitude is 8 8/9 *yojanas*.

Note. Since the degrees of latitude are zero at the equator and 90 at the N.pole, and the same to the S.pole, in the visible half of the meridian circle, the circumference of the earth is 360° equal to 360 × 8 8/9 *yojanas* = 3200 *yojanas*. Āryabhaṭa's *yojana*-measure is very nearly VM's.

16. Thus for 90°, there are 800 *yojanas*, calculated. When an observer on any meridian sees the Sun rising, it is midday on the meridian 800 *yojanas* (east) of him.

Note. The mean sunrise is meant here since the actual sunrise is affected with *cara:*

14-17 Quoted by Utpala on *BS* 2, p.58.

14a. B.वक्रस्यार्धे
A. त्र्यखमध्यात; B. त्र्ययखमध्यते
b. A.B.राशयस्तेशाः; C.D.राशयस्तेंऽशाः
c. A.खडंगानि; B1.3.चं षडंगानि; B2.च खडङ्गानि
d. B.उदयात्त परि
15a. B.एकैकोशो; U.एकैकांशो
A.B1.2.नवतिः
b. A.यात्ति; C.D.U.योजनैर्भवति
c. A.समं दक्षिणोत्तरायणं; B.समदक्षिणोत्तरापणं; U.स च द०
d. A.B.D.प्रत्यक्षे; C.U.प्रत्यक्षः A. ध्यैथयं; B.ध्येप्ययं; C.U.खेप्ययं; D.ध्येयः
A.D.खमध्यात्
16a. A.B.एवं नववृत्यांशै
b. B.दष्टौ दष्टानि योज०
c. C.D. om स हि
C. तत्प्रमाण्यादेशे; D. तत्प्रमाणादेशे. B. दुष्टु

[लङ्कोज्जयिन्योः स्थानम्]

उज्जयिनी लङ्कायाः सन्निहिता योत्तरेण समसूत्रे |
तन्मध्या(ह्नो) युगपद् विषमो दिव(सो) विषुवतोऽन्यः || १७ ||

Position of Lankā and Ujjayinī

17. The mid-day of Laṅkā is the same as that at Ujjain, which is north of Laṅkā on the same longitude. But their day-time durations are different, except when the Sun is on the equator.

[भूमानादि]

योजनशतानि भूमेः परिमाणं षोडश द्विगुणितानि |
तापयति मेरुमध्यात् विषुवस्थोऽर्कः क्षितिं [चैवम्] || १८ ||
षडशीतिं पञ्चशतीं त्रिभागहीनं च योजनं गत्वा |
क्षितिमध्यमुदगवन्त्या लङ्काया योजनाष्टशतीम् || १९ ||

Measures of the earth etc.

18. The circumference of the earth is 3200 *yojanas*. When situated on the equator, the Sun is visible from pole to pole at all latitudes, (making the day and night equal).

19. The middle of the earth, (the North pole is meant here), is north of Ujjain by 586 2/3 yojanas. It is north of Laṅkā by 800 yojanas.

Note: The distance in latitude from Laṅkā to Ujjain is 24°, and from Ujjain to the North Pole is 66°. Thus $66 \times \sqrt{8\ 8/9} = 586\ 2/3$, and $90 \times 8\ 8/9 = 800$.

[रवेर्दृश्यादृश्यत्वम्]

प्रतिविषयमुदक् तुङ्गो हरिजाद्यावद् ध्रुवः खमध्यात्तु |
दिनकृदपि नमति विषुवति दक्षिणतस्तावदेवांशैः || २० ||
त्रिशतीं त्रिसप्ततियुतां यात्वोदक् योजनत्रिभागं च |
उज्जयिनीतो विघटति पर्याप्तोऽयं भगणगोलः || २१ ||

17a. A.B2.ऊज्जयिनी; B1.3.ऊनीयिनी A.B1.2.लंकाया स॰; B3. लङ्का स॰
b. B. सति हितायोन्त्तरेण समस्तत्र |; B3. समस्तत्रो
c. A.B. मध्याह्ने
d. A.B. दिवसे (B2.3. ॰सो)
A1. विषुवतोन्यः; A2. वि.... वतोन्यः; B2.3. वतेभ्यः;
B1. वतोन्यः

18-19 Quoted by Utpala on *BS* 2.p.58.

18c. A. तायपति; C. तद् भ्रमति A. मेरुमध्यद्
d. A.B. विषुवस्थोर्कों A.B.C. क्षितिरेवं; D. क्षितिमेकं
19a. A. ॰शीति पंच B. पञ्चशति
b. B. योऊनं. U. ॰नं भित्वा
d. A.B1.3. लंकायां. B. ॰ष्टशतिः

Visibility of the Sun

20. At any latitude, the equatorial Sun is bent so many degrees south at midday, as the north pole is raised up from the north point of the horizon.

21. Going north from Ujjain, 373 1/3 *yojanas*, the stellar sphere, (marked by the 27 asterisms of the ecliptic rising in an order) becomes discontinuous, (i.e. the order in the rising is disrupted).

Note. At 66° North latitude, which is 42°, (i.e. 66° − 24°), north of Ujjain, peculiarities occur in the rising of the signs of the ecliptic, duration of day-time etc. 42° = 373 1/3 *yojanas*.

(षष्टिर्नाड्य)स्तस्मिन् सकृदुदितो दृश्यते दिवसनाथः |
परतः परतो बहुतरमा षण्मासादिति सुमेरौ || २२ ||
योजनपञ्चनवांशां स्त्र्यधिकांश्च चतुःशतीमुदगवन्त्याः |
गत्वा न धनुर्मकरौ कदाचिदपि दर्शनं व्रजतः ||२३ ||

22. At that latitude, the Sun can be visible even throughout a day. North and north of this place, the Sun may not set more and more than one day, until at the north-pole it will not set for six months at a stretch.

23. At a distance greater than 403 5/9 *yojanas* north of Ujjain, the signs Dhanus and Makara can never be visible.

Note. The Dhanus and Makara segments of the ecliptic have a south declination greater than 20° 36′. In the north latitudes 90° − 20° 36′ (= 69° 24′) and beyond, the zenith distance of these signs becomes greater than 90°, and so they are not visible in those latitudes. 69° 24′ is 45° 24′ north of Ujjain, i.e. 45° 24′ × 8 8/9 = 403 8/9 *yojanas* north.

20-29. Quoted by Utpala on *BS* 2, p.58-59.
20a. B.विषमुदक्तंगो
b. A.हरियाद्याद्या ध्रुवः; B.हिरिया छान्वा ध्रुवः B2.खमध्या तु
c. B.दिनक्तदपि ममति A1.विषुवविदक्षि; B.रिपुवति (B2.रिषुवति)
d. A. दक्षिणतस्त्राव
21a. A1.त्रिशति; A2.त्रिशतिं; B.त्रिशति. A2.सप्ततिं युतां
b. A.C.D.गत्वोदक्; B.गचोदक् A2.योजं न. A.विभागं च
c. A.B.C.D.विरमति
d. A.B1.2. C.D.पर्यस्तोऽयं. B.भगणं गोलः
22a. A.षष्टी नाडी; B.षष्टिं नाडीं (B3.नाडी) C.D.षष्टिं नाडीः
b. B1.3.सदुदितो; B2.मदुदितो
c. A.B1.॰वहुतर॰
23a. B.योनपञ्च॰ A.नवांशाः; U.नवांशान्
b. A.C.स्त्र्याधिक्यं; B.स्त्र्यधिका; D.स्त्र्यधिकां च A.B.D.सचतुः (A1.सवतुः; A2.सवनुः) C.शत. B3.मुदगवत्याः
c. B.गचान A. धनुर्मकरं; B2. धनुर्मकरा
d. B1.दर्शन व्रजतः

तस्मादेव स्थानाद् द्व्यशीतियुक्तां चतुश्शतीं साग्राम् |
(नोदयमुपयान्त्यलिमृगधटचापधराः) कदाचिदपि || २४ ||
षडशीतिं पञ्चशतीं त्र्यंशोनं योजनं च तत एव |
गत्वाऽन्त्यं चक्रार्धं नोदेत्याद्यं न यात्यस्तम् || २५ ||
लङ्कास्था भूलग्नां नभसो मध्यस्थितां च मेरुगताः |
ध्रुवतारामीक्षन्ते तदन्तरालेऽन्तरोपगताः || २६ ||

24. At latitudes north of Ujjain greater than 482 *yojanas* and a fraction Vṛścika, Dhanus, Makara and Kumbha signs will never be visible.

Note. These four signs have a declination greater than 11° 44′ south. Therefore latitudes 90° − 11° 44′ = 78° 16′ North and more cannot see these signs, since their zenith distance is greater than 90°. 78° 16′ is 54° 16′ north or Ujjain = 54° 16′ × 8 8/9 = 482 10/27 *yojanas.*

25. 586 2/3 *yojanas* north of Ujjain, i.e. at the North pole, the second half of the ecliptic, i.e. the signs Tulā to Mīna, cannot be seen.

Note. Being situated south of the celestial equator, the zenith distance of these signs from the North pole is greater than 90°, and therefore they are not visible at the North pole. The distance of the North pole from Ujjain is 90° − 24° = 66° = 586 2/3 *yojanas*.

26. People on the equator see the North polar star on the horizon. At the North pole, people observe it at the zenith. In between, people observe it at attitudes 0° to 90°.

Note. As the north latitude increases, so the latitude of the Pole star increases equally. This fact is mentioned elsewhere also.

सकृदुदितः षण्मासान् दृश्योऽर्को मेरुपृष्ठसंस्थानाम् |
मेषादिषु षट्सु चरन् परतो दृश्यः स दैत्यानाम् || २७ ||
मेषस्तेषां नित्यं लग्नं त्र्यंशश्च भूमिपुत्रस्य |
त्रिंशद्भागनवांशद्वादशभागाश्च तस्यैव || २८ ||

24a. A. स्थाना B. ॰द्यशीति
b. A. ॰शतीं साग्रं; B1.3. शतीत्यागाम्; B3. ॰शतीसागां; D. ॰शतीं त्याग्य
c. A. नोदयमदयांतपलि॰; B. नोदयसु (B2. मु) दयां सलि॰;
C.D. नोदयमिह यान्त्यलि; U. दृष्टिपथं नो यान्त्यलि
d. B1.3. घर्ठचाप U. om अपि
25a. A. षडशीतां; B1.3. षडशीतीं and B2. षडशतीं in place of पञ्चशतीं
c. A1. गत्वाच्य; B1.3. गस्वात्यं; B2. गवान्त्यं B. चक्रार्प्त
d. A. नोत्पाद्यं न यात्पस्तं; B. नोसाधं (B2. त्याधं) न यात्यंस्तं
26a. A.B. भूलऽना
b. B. नमसो A. मध्यां स्थि; B. मध्या ये (B2. य) मे॰ A.B. मेरुगता
d. B1. तदन्तले; B3. तदन्त-ले A.B1.2. रेपगताः; B3. रेपगता

विषुवल्लेखाऽधस्ताल्लङ्का तस्यां समो भगणगोलः |
त्रिंशन्नाड्यो दिवसः त्रिंशच्च तस्यां सदा च निशा || २९ ||

27. For the people on Meru, i.e. at the North Pole, the Sun is visible at a stretch, when it is in the six signs Meṣa to Kanyā. When it is in the next six signs, it is visible to the demons at the South pole, at a stretch.

Note. Moving in the first six signs, the Sun's zenith distance is less than 90° at the North pole and it is visible to the Devas there. Being greater than 90° at the South pole it is invisible to the Asuras at the South pole. It is vice versa in the next six signs. Thus the Devas and the Asuras have their day and night alternately, each for six months at a stretch.

28. For them, the first point of Meṣa is the *Lagna* or Orient ecliptic point, permanently, Mars is the Lord of the *Drekkāṇa, Navāṁśa, Dvadaśāṁśa* and *Triṁśāṁśa lagnas* permanently.

Note. The first point of Meṣa moves round and round there on the horizon, and no other point rises or sets. The lordships are as prescribed in the *Horāśāstra.* There the Lord of Meṣa is not only the master the *Rāsi-lagna,* but also of *Drekkāṇa, Navāṁśa* etc. lagnas.

29. Laṅka is beneath the celestial equator, i.e. the celestial equator itself is the prime vertical at Laṅkā. There the stellar sphere is equally divided (into the northern half with the N.P. at its centre, and the southern half with the S.P. at its centre). There the day and night are always 30 *nāḍīs* each.

Note. This is because all diurnal circles of the Sun are divided into two equal halves by the equatorial horizon. Note also that what is said of Laṅka applies to all places on the equator.

[वेधप्रकारः]

सलिलेन समं कृत्वा तुङ्गं फलकं यथादिशं दृष्ट्वा |
दक्षिणकोट्यां शङ्कुं फलकप्रमितं व्यवस्थाप्य || ३० ||

ऋजुशङ्कुबुघ्नविन्यस्तलोचनो नमयेत्तथा शङ्कुम् |
भवति यथा शङ्क्वग्रं ध्रुवता दृष्टिमध्यस्थम् || ३१ ||

पतितेन भवति वेधो लङ्कायां ऊर्ध्वगेन तु सुमेरौ |
विनतेन च तथान्तराले फलके (चाक्षोर्ध्व)सूत्रसमम् || ३२ ||

27a. B1.3.सत्तदुदितः; B2.सततुदितः
b. B.भेकपृष्ट
c-d. B.षड्गुवरन्यस्तो (B2.वन्त्यस्तो) दृश्यः
28a. A.लग्ने; B.लगोत्यंशश्च
b. B.पुत्रः स्यात्
d. B.तस्मैव

29a. B.विषुवध्त्रे (B2.ल्ले) खाधस्ताछ्त्रै (B2.ल्ल) ङ्का
c. B.त्रिंश नाड्यो A.B.द्विवस
d. A.B.C.D.U.त्रिंशत्तस्यां च सदा (A.सहा) (B1.2.शदा; U.निशा)

Astronomical observation

30-32 Place a plank in a raised position, with its surface plane, as examined by dropping water on it. Set it so as to have its surface horizontal and level with the eye, and its parallel sides north-south and east-west. At the southern edge, in the middle, hinge a sighting tube (*śaṅku*) equal in length to the north-south length of the plank. With the eye at the hole of the rigid sighting instrument, at the hinge, lower the instrument so much, that the North-pole-star is sighted through the hole of the instrument. When lowered completely, (the observation) will be towards Laṅkā: when vertical it will be towards Meru; and lowered appropriately, it will be equal to the (local) latitude (as read) from the plank.

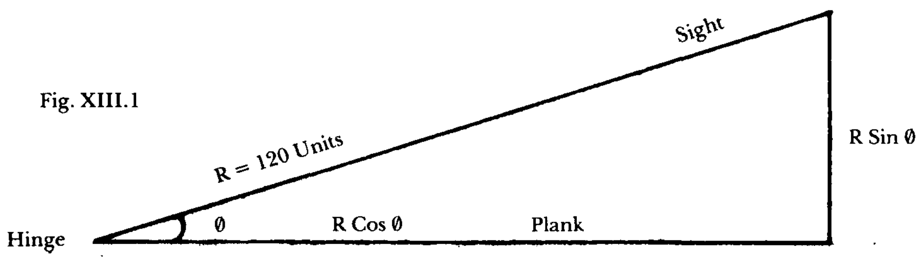
Note. From the next verse we can understand that V.M. implies here that the north-south length of the plank is 120 units, so that the length of the sighting instrument also is 120 units = R. So taken, the perpendicular dropped on to the plank from the end of the instrument will be equal to R sine raised angle, and the base from the foot of the perpendicular to the hinge will be R cos. raised angle.

तत्राऽवलम्बको यः सोऽक्षज्या तस्य शङ्कुविवरं यत् |
विषुवदवलम्बकोऽसौ याम्योत्तरदिक्प्रसिद्धिकरः || ३३ ||

33. When so sighting the pole-star, the perpendicular, dropped on to the plank from the end of the sight is the R.sine of the latitude of the place. The base so formed is the R cosine of the latitude of the place. The R cosine line, i.e. the base, coincides with the north south-direction line.

Note. VM uses a table of R sines, taking R = 120 units. Hence the rule.

Fig. XIII.1



30-34. Quoted by Utpala on *BS* 2.p.59.

30a. B.सभक्तता तुगं;
b. B.फलर्क. C.D.U.दृष्ट्या
c. A.कोद्यां; B.कोधां. A.शङ्कु; B1.2.शंशंकुं
d. A1.प्रंतिम; A2.प्रतिम; B.प्रतिम
B.व्ययं व्यवस्छाप्य

31a. B.रुजुशंकु (B3. om कु) A.वुघ्र्य; B.बुध्र्य
b. B.नामये; A.C.D.नामयेत्. A2.शङ्कु
c. B.शष्कुवग्रं
d. A.B.C.D.ध्रुवतारादृष्टि

32a. A2.चेधो
b. B.लम्बतया A.B.मूर्धं (B.र्द्धं) गेन (B.नं) तु
c. A.चान्तराल; B.चान्तराला; C.D.चान्तराले
d. A.छोद्यार्धसूत्रसमे; B.छोधर्द्ध सूत्रसमाः (B2.समोः);
C.फलकच्छंदार्धसूत्रसमे |; D.फलके भासार्थसूत्रसमे |;
U.फलकच्छेदार्धसूत्रसमे |

33a. A.लंवोको य; B.लवको य
b. A.B.सोरज्या;
B.शकुविवरं यत्तं (B3.तं)
c. A1.०लंकोसौ; B.लंडकोसौ

स्वप्रत्ययेन सन्तो विज्ञायैवं वदन्ति भूमध्यम् |
सकलमहिमानं वा रसमिव लवणाम्भसाऽल्पेन || ३४ ||

34. Learned men, observing things for themselves thus, determine the North pole, the dimensions of the whole earth, etc. as one would determine the salty taste of the whole quantity of the solution by tasting a small quantity of it.

Note. What is meant here is that observation made at a small place on the earth can give us knowledge of the whole earth, by suitable reasoning.

[चन्द्रशौक्ल्यम्]

नित्यमधःस्थस्येन्दो (र्भाभि) र्भानोः सितं भवत्यर्धम् |
स्वच्छायायाऽन्यदसितं कुम्भस्येवातपस्थस्य ||३५ ||

सलिलमये शशिनि रवेर्दी (धित) यो मूर्छितास्तमो नैशम् |
क्षपयति दर्पणोदरनिहिता इव मन्दिरस्यान्तः || ३६ ||

प्रतिदिवसमेवमर्वाक् स्थानविशेषेण शौक्ल्यपरिवृ (द्धिः) |
भवति शशिनोपरा (ह्ने) पश्चाद्भागे घटस्येव || ३७ ||

Moon's luminosity

35. The Sun lights up one half of the Moon situated below it always, (at any position round the earth), and the other half is dark by its own shadow, (i.e. the Moon obstructing the sun-light by its own body) just like a pot placed in sun-light.

Note. This is because the Moon gets its light from the Sun, and is not self-luminous.

36. The Sun's rays, reflected in the watery Moon dispels the darkness on the earth, just as the rays of the sun falling on a mirror in the interior of a house, does.

Note. It is the belief of the ancients that the Sun is fiery, the Moon watery and the earth mainly earthy.

37. According to the position of the Moon underneath the Sun, every day, the lighted up part increases (from the time of new moon, as seen from the earth), as the lighted portion increases on the pot, on the western side, in the afternoon.

Note. Instead of the expression, after-noon a better one would be, 'as the day-time elapses, beginning from sunrise.'

34c. B1.3.सकर्ल

d. A.B.D.रसमि—लवणाम्भसोऽल्पेन; (B.रसमितं; D.रसमिव)

असितात् सिताच्च पक्षाद् असितं पक्षार्धमर्कमीक्षन्ते ।
राशित्रयादुभयतो नभो यतः शीतकरसंस्थाः ॥ ३८ ॥

38. Anywhere on the Moon, its denizens, (the *Pitṛs*, in this case) see the Sun for half the time during each fortnight, (on the whole, not seeing the Sun for a fortnight's time, and seeing it for a fortnight's time), because the visible part of the sky extends only upto 90° from the zenith.

[ग्रहाणां स्थानम्]

चन्द्रादूर्ध्वं बुधसितरविकुजजीवाऽर्कजास्ततो भानि ।
प्राग्गतयस्तुल्यजवा ग्रहास्तु सर्वे स्वमण्डलगाः ॥ ३९ ॥

तैलिकचक्रस्य यथा विवरमराणां घनं भवति नाभ्याम् ।
नेम्यां स्यान्महदेवं स्थितानि राश्यन्तराण्यूर्ध्वम् ॥ ४० ॥

पर्येति शशी शीघ्रं स्वल्पं नक्षत्रमण्डलमधःस्थः ।
ऊर्ध्वस्थस्तुल्यजवो विचरति तथा न महदर्कसुतः ॥ ४१ ॥

The Planets and their situation

39. Beyond the moon are orbiting higher and higher, Mercury, Venus, the Sun, Mars, Jupiter and Saturn, and beyond that there are fixed stars. All the planets (from Mercury to Saturn) move in their own individual orbits at a constant speed.

Note. All this is Hindu theory.

40. Just as the spokes of the oil-press wheel are thick, (close to one another), near the navel, and the space between one another increases as the rim is approached, so the linear extension of the *rāśi* increases as the orbits are situated higher and higher.

35a. Quoted by Pṛthūdaka on *BrSS* 21.8 end, 36 quoted by Sūrydeva on *Abh.* Gola. 5, and Makkibhaṭṭa on *Sid. Śekhara* 1.1.

35a. A2. भित्यमथ A. स्येंदोः; D. °स्येद्रोः
A.B. भवति भानोः
c. A. स्वछायान्पदसितं
36a. B. सलिलमपे. A. ये च शशिनि. A. र्दिधयो (A2. दी);
B. - धत्तयो
c. A.B. क्षपयन्ति

d. B. इमं वयं हरिस्यान्तः
37a. A.C.D. °मर्कात्
b. B. विदोषेण शौक्य A. परिवृधिः
d. B. घटस्येवा

38a. B. अप्रसिता सिताश्च
b. B. °मीक्तन्ते
c. A. °त्रयादूभ; D. °क्षयादुभ
d. A. मभोयतः; B.C. नभो यत (C. °तः);
D. न भान्य [था] तु. B. गेतीतकर

41. Situated near-most, the Moon goes round in the shortest time, its orbit being the shortest. But Saturn situated farther-most, in its longest orbit, cannot move so fast, i.e. moves slowest.

[मास-दिन-वर्षाधिपाः]

मासाऽधिपा यथो(र्ध्वं) चन्द्रात् सौरादधश्च होरेशाः |
ऊर्ध्वक्रमेण दिनपाश्च पञ्चमा वर्षपाः (षष्ठा) ||४२ ||

Lords of the Months, Days and Year

42. The successive Lords of the Month are the successive farther planets, beginning from the Moon. The Lords of the Horās are the successive nearer and nearer planets, beginning from Saturn. The successive fifth in the ascending order of its distance is the successive Lord of the Day. The sixth in its ascending distance order is successively the Lord of the year.

Note. The month meant here is the *sāvana* month of 30 days, and the year, the *sāvana* year of 360 days. We get the lords of the *horās;* Saturn, Jupiter, Mars, Sun, Venus, Mercury, Moon, Saturn etc. the lords of the day, Sunday, Monday, etc., the lords of the months, Moon, Mercury, Venus, Sun, Mars, Jupiter, Saturn, Moon etc., and the lords of the year, Moon, Jupiter, Sun, Mercury, Saturn, Mars, Venus, Moon etc.

[इति पञ्चसिद्धान्तिकायाम् वराहमिहिरविरचितायां
त्रैलोक्यसंस्थानं नाम त्रयोदशोऽध्यायः ||] [1]

Thus ends Chapter Thirteen entitled 'Situation of the Earth: Cosmogony' in the Pañcasiddhāntikā composed by Varāhamihira

39-41. Quoted by Utpala on *BS*, 2, pp. 42-43

39a. A. चन्द्रादूर्ध्वंवुधसितं (A2. बुध); B1.2. चन्द्राषुधखित; B3. चन्द्राद्बुधस्वीत
c. B. प्रागातरा (B3. प्राणां)
A. स्तुल्पजवा; B. -ल्पजवा
d. A. ग्रहाः स्तु. B1.3. मण्डलर्गाः
40a. B1.3. तैलक
b. B. विपर. B. ना ध्रुभ्या
c. B. मेम्यं स्या
c-d. U. नेम्यां महदेवं संस्थितानि
d. B. देवस्छितानि. A. ॰यूर्ध्वं; B. ॰यूर्द्धम्

41a. B. राशिशीघ्रनक्षत्रं (B2.3. शीघ्रं न)
b. B. मध्यस्थः
c. A. ऊर्धस्थस्तुलजवो
d. B. विवरति
A.B. om तथा; C.D. om न;
U. ॰जवोऽपि संस्थितस्तथा॰

42a. A.B. मासाधिपो यथोर्धां (B. र्द्धाः)
b. चन्द्रा
c. A. ऊर्ध्वं; C.D. ऊर्ध्वं. A. दिनपा च; B. ष्मिपा च
d. A.B. पंचमास्याः A.B.C.D. स्पष्टाः

1.col. A. त्रैलोक्यसंस्थानं त्रयोदशोध्यायः B.C.D. इति (B. om इति) त्रै (B1.2. सै) लोक्यसंस्थानं नाम त्रयोदशोऽध्यायः

Chapter Fourteen

GRAPHICAL METHODS AND ASTRONOMICAL INSTRUMENTS*

१४. चतुर्दशोऽध्यायः

छेद्यक-यंत्राणि

Introductory

In chapter I, vss. 5-7, Varāhamihira enumerated *yantra* and *chedyaka* among the topics to be dealt with in the present work. The present chapter deals with these two topics.

The compound word *chedyakayantrāṇi* is equivalent to the compound word *yantracchedyāni* of I. 7. The word *chedyaka* means graphics or graphical methods and the word *yantra*, in the present context, means astronomical instruments.

Dvivedi interpreted the word *chedyakayantrāṇi* as follows: "That which cuts or removes doubts is *chedyaka*; the instruments which serve as *chedyaka* are *chedyakayantrāṇi.*" If it were so, there would be no difference between *yantra* and *chedyakayantra. Chedyaka* and *Yantra,* in fact, are two distinct topics of Indian astronomical works called *Gola* or Spherics. Lalla, Vaṭeśvara and Bhāskara II, for example, have earmarked two separate chapters for their treatment in their works on spherics. Pingree, on the other hand, translates *chedyakayantrāṇi* as "the Magical Diagrams of the (Graphical) Constructions." But the diagrams or astronomical instruments discussed in the present chapter bear no magical significance.

[चरः]

साशीतिकाङ्गुलशतं विस्तीर्णवृत्तमविषमं धरित्र्याम् |
समराश्यंशकचिह्नं परिधौ सापक्रमं कुर्यात् || १ ||

याम्योदक्समसूत्रादपक्रमांशावगाहिभिः सूत्रैः |
प्रथमवदङ्कक्षिप्तं वृत्तत्रयमालिखेन्मध्यात् || २ ||

अक्षे क्षिप्तां लेखां [प्र]कुर्याच्च भगणचिह्नपर्यन्ताम् |
अक्षोत्तरलेखान्तरमपक्रमांशोत्थमादाय || ३ ||

द्विगुणं प्रसार्य वृत्ते स्वे[दिक्] तच्चापांशदलाभ्यस्ताः |
प्रथमर्क्षचरविनाड्यो ज्ञेयाः परिशेषयोर्मिश्राः || ४ ||

GRAPHICAL METHODS

Ascensional differences of the zodiacal signs.

In III, 10-12, Varāhamihira stated an approximate practical method for finding the ascensional differences of the signs for places living between the Indian Ocean and the Himalayas and prom-

* This chapter was left untranslated by T.S. Kuppanna Sastri. The translation given here was supplied by K.S. Shukla.

ised to give a method for other places in a subsequent chapter devoted to *chedyaka*. The following rule is in fulfilment of that promise.

> 1. Construct on the ground a level circle with diameter equal to 180 digits. On its circumference put down, at equal distances, marks showing signs and degrees (etc.). Also put down marks showing the declinations (of the end-points of the signs Aries, Taurus and Gemini). (Through the centre of the circle draw the north-south line and at right angles to it draw three chords through the marks showing the declinations for the ends-points of the signs Aries, Taurus and Gemini).
>
> 2. From the centre, draw three circles with diameters equal to the three chords which have been drawn through the declination marks at right angles to the north-south line, and graduate them with marks (of signs and degrees) like the first circle.
>
> 3. Then (from the same centre) draw a line towards the latitude (i.e. towards that point of the first circle which marks the latitude of the place) and extend it upto the mark (indicating the latitude of the place) on the circumference of the first circle. (This is the latitude-line). On the chord corresponding to the desired declination (*i.e.* declination of the end-point of the desired sign), measure the portion lying between the latitude-line and the north line (i.e. the line drawn from the centre to the north point).
>
> 4. Lay off the double of that (like a chord) on the corresponding circle. Ten multiplied by one-half of the degrees in the arc subtended by that chord are to be known as the *vināḍīs* of ascensional difference in the case of the first sign. In the case of the other two signs, they are the *vināḍīs* of the mixed ascensional difference (i.e., the mixed ascensional difference of Aries and Taurus and the mixed ascensional difference of Aries, Taurus and Gemini).

Consider Fig. 1. ENWS is the level circle of diameter 180 digits drawn on the ground, E, W, N and S being the east, west, north and south cardinal points, respectively. EW is the east-west line and NS the north-south line. The arcs Ed_1, Ed_2 and Ed_3 are equal to the declinations δ_1, δ_2 and δ_3 of the end-points, of the signs Aries, Taurus and Gemini respectively. $Wd' = Ed_1$. $Wd'' = Ed^2$ and $Wd'' = Ed_3$. d_1d', d_2d'' and d_3d''' are the three chords corresponding to the declinations δ_1, δ_2 and δ_3, respectively. These are at right angles to the north-south line.

1c. A. राश्यंकचिह्नं C. राश्यंङ्क चिह्नं
d. A. मापक्रमं; B. मायक्रमः

2b. B. पद for दप B2.3. क्रमाशा
c. AB. ॰वदंकाक्षिप्रं; (B. gap for व)
d. A2. वृत्तं; B. वृत्ततुत्रय

3b. A. om प्र A. कुर्याक्च भगणपर्यन्तां;
B. कुर्यार्कलंगणपर्यन्तात् (B1.2. ॰कर्यार्क॰)
c. B. अक्षेतर
d. A.B. ॰शोच्छमादाय (B2. शोछ)

4a. B. द्विगुण B1.3. प्रसार्प; B2. प्रस्तार्प B. वृशौ
b. A.B. om दिक् B. नवापांशकादलाभ्य (B1. भ) स्ताः
c. A. विनाड्ये; B. विनाप्रे
d. B2. न्तेथाः B3. मिश्रा

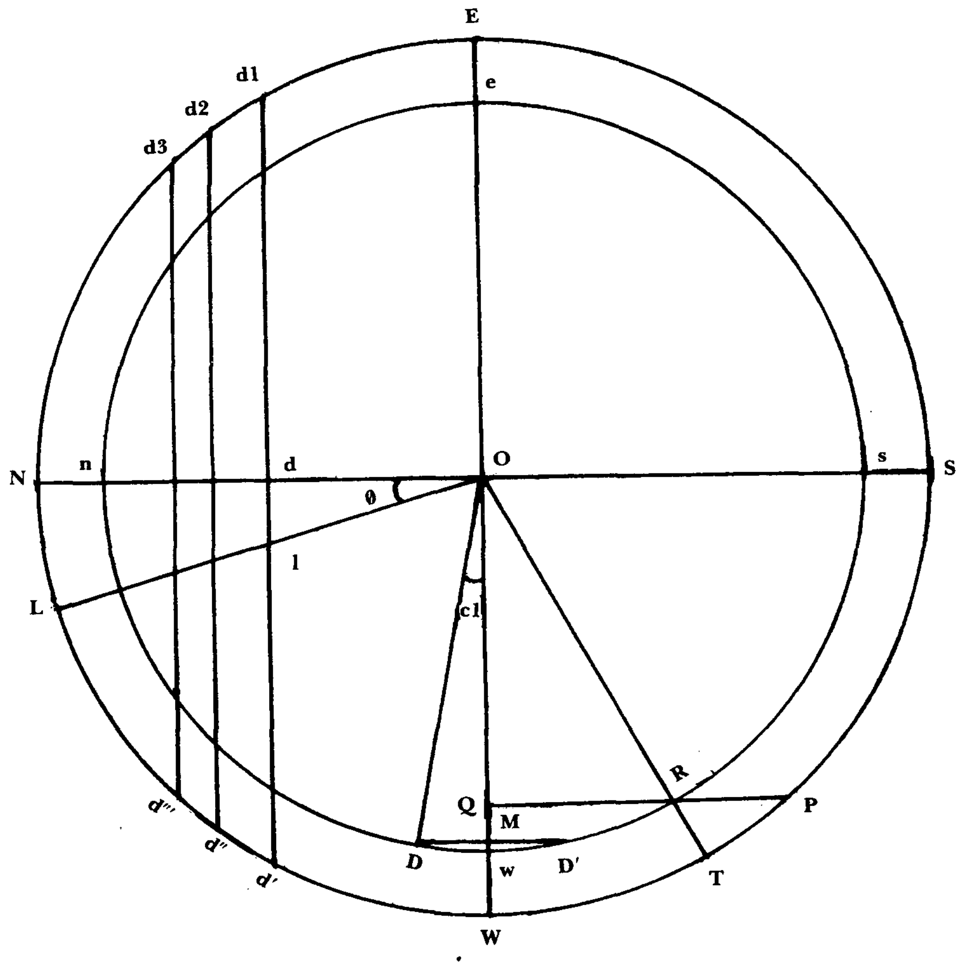


Fig. XIV.1

The arc NL is equal to the latitude ϕ of the place, L being the point marking the latitude of the place. OL is the latitude-line drawn from 0 to meet the point L. ON is the north line.

enws is the circle drawn with centre 0 and diameter d_1 d'. (The other two circles drawn with diameters d_2 d'' and d_3 d''' are not shown in the figure). dl is the portion of the chord d_1 d' lying between OL and ON. In the triangle Odl,

$$Od = R\sin\delta_1$$

$$dl = Od.\tan\phi$$
$$= R\sin\delta_1.\tan\phi, \qquad (1)$$

R denoting the radius of the circle ENWS.

The chord DMD′ of the circle enws, with its middle point at M, is equal to 2dl. Let $2c_1$ be the angle subtended by DD′ at 0 (or, wdhat is the same thing, the arc DWD′ subtended by DD′). Then

$\frac{1}{2}$ DD′ = DM = OD sin c_1 = Rcos δ_1. sin c_1.
$\frac{1}{2}$ DD′ = dl = Rsin, δ_1. tan ∅, from. (1).

∴ Rcos δ_1 sin c_1 = Rsin ϵ_1. tan ∅.
∴ sin c_1 = tan δ_1. tan ∅ (2).

This c_1 is the ascensional difference of the end point of the sign Aries, or the ascensional difference for the sign Aries. See supra, IV. 26. See also IV. 34.

Since c_1 is equal to the number of degrees lying in half the arc DwD′, therefore the degrees in half the arc DwD′ give the ascensional difference of the sign Aries. These degrees multiplied by 10 give the corresponding *vinâḍîs*.

Similarly, in the case of Taurus and Gemini. But in these cases if c_2 and c_3 be the ascensional differences for the end-points of Taurus and Gemini respectively, then
ascensional difference for Taurus = $c_2 - c_1$
and ascensional difference for Gemini = $c_3 - c_2$.

[नाडीतः छाया छायातः नाडी च]

नाड्यः (षड्घ्न्यो) भागास्तज्ज्या व्यासार्धशोधिता छाया |
माध्यन्दिनीसमेता नाड्यर्थे सा तया हीना ||५ ||
छायाहरिजाभ्यन्तरजीवाचापांशषष्ठभागो यः |
ता नाड्यः (प्राग् याताः) पश्चाच्छेषास्तथा (प्राप्ताः) || ६ ||

Rsine of the Sun's zenith distance for the given time, (and vice versa).

5. The *nâḍîs* (elapsed since sunrise in the forenoon or to elapse before sunset in the afternoon) multiplied by 6 are degrees; the (versed) Rsine of that subtracted from the radius (R) and then increased by the Rsine of the Sun's zenith distance for midday gives the Rsine of the Sun's zenith distance (for that time). In order to find the *nâḍîs* (from the given Rsine of the Sun's zenith distance) the (given) Rsine of the Sun's zenith distance should be diminished by the Rsine of the Sun's zenith distance for midday.

6. Whatever is the sixth part of the degrees of the arc corresponding to the (versed) Rsine equal to the difference between the given Rsine of the Sun's zenith distance (as diminished by the Rsine of the Sun's zenith distance for midday) and the radius (*chāyāharijābhyantara*), gives the *nāḍīs* elapsed since sunrise in the forenoon or to elapse before sunset in the afternoon.

Let n be the *nāḍīs* elapsed since sunrise in the forenoon or to elapse before sunset in the afternoon, and z_0 the Sun's zenith distance at midday. Then, according to the rule stated in verse 5 above, the Rsine of the Sun's zenith distance for that time (which we shall denote by Rsin z) is given by

$$\text{Rsin}z = R - \text{Rvers}(6n) + \text{Rsin } z_0, \quad (3)$$

where R stands for the radius.

This relation is approximately correct for a place on the equator, and is accurate at an equinox. For any other place it is incorrect, for Rsin z really depends upon ∅, the latitude of the place, and the Sun's declination on the day in question, besides the time of the day elapsed since sunrise in the forenoon or to elapse before sunset in the afternoon. Any such formula must therefore involve these elements.

Formula (3) stated above does not occur in any other work on Indian astronomy. But analogous formulae do occur. Of these mention may be made of the following.

(i) *Vasiṣṭha's formula.*

Let s_0 denote the gnomonic shadow at midday and s the gnomonic shadow at any other time. Then, in the forenoon:

$$s = \frac{64800}{(lagna - \text{Sun}) \text{ in mins.}} - 12 + s_0$$

and in the afternoon

$$s = \frac{64800}{10800 - (lagna - \text{Sun}) \text{ in mins.}} - 12 + s_0$$ (see above II.12-13)

(ii) *Pauliśa's formula*

$$s = \frac{6 \times \text{day-length}}{\text{day elapsed}} - 12 + s_0$$ (gnomon = 12. See IV. 49.

This formula was later restated by Mahāvīra in the form:

$$s = \frac{\text{gnomon}}{2 \text{ day elapsed / day-length}} - 12 + s_0$$ (gnomon = 12. See *Gaṇita-sāra-saṅgraha*, IX. 18).

(iii) *Śrīdhara's formula*

$$s = \frac{^1/_2\, gnomon}{\text{d}} = \text{gnomon, where d} = \frac{\text{day elapsed or to elapse}}{\text{day-length}}$$

See *Triśatikā* (ed. Sudhākara Dvivedi), Rule 65.

This may be derived from Pauliśa formula by assuming $s_0 = 0$.

Śrīdhara's formula was restated by Nārāyaṇa Paṇḍita in the form:

$$s = \left\{ \frac{\frac{1}{2} \text{ day-length}}{\text{day elapsed or to elpase}} - 1 \right\} \times \text{gnomon}$$

See *Gaṇita-kaumudī*, Rule 13, p. 207.

5a. A.षड्या भागा; B.ष (B2.श्र) मश्रध्यामागा (B2.°सागा)
b. A.तज्या
c. A.साध्यंदिनी B.समेत्ता

6a. B2.छया
ab. B.°भ्यन्तरजा जीवा
b. A.षष्ट; B1.2.षष्टं; B3.षष्ठं
c. A.प्राग्यतः; B.प्राग्युता
d. A.B.पश्चाछेषा° A.स्नथा C.°स्तुया A.प्राप्रो; B.प्राप; C. [प्राची]

Formula (3) may also be stated in the form:
Rvers $(6n)$ = R − (Rsin z − Rsin z_0), so that
n = one-sixth of the degrees in the arc corresponding to the versed Rsine equal to R − (Rsin z − Rsin z_0). Hence the rule stated in vs. 6.

[राश्युदयः]

तिर्यग्रेखा समदक्षिणोत्तरापक्रमांशरेखायाम् ।
तच्चापांशा दिग्घ्नाः राश्युदयविनाडिकाः क्रमशः ॥ ७ ॥

Right ascensions of the signs (defined by means of the armillary sphere)

7. The degrees in the arcs of the equator which lies orthogonally (*tiryak*) between the north-south declination arcs for the ends of the signs, multiplied by 10, are the *vinâḍîs* of the right ascensions of the signs (Aries, Taurus and Gemini) in their respective order.

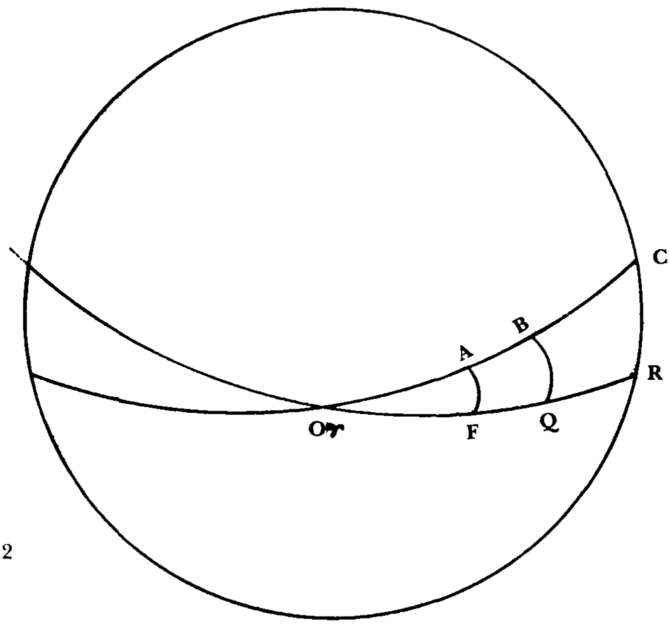


Fig. XIV.2

In Fig. 2, ♈R is the equator and ♈C the ecliptic. AP, BQ and CR are the declinations for the end-points of the signs Aries, Taurus and Gemini, respectively. Then

♈P is the right ascension of Aries,
PQ is the right ascension of Taurus,
and QR is the right ascension of Gemini.

7a. C. रेखासम°
b. A. °रावक्रमांश; B. °राचक्रमांशा A.B. रेखायाः
c. A. दिघ्नाः; B. दि—राश्युं
d. A. विनाडिका क्र° A. क्रमंशः, B. क्रमशा

i. *Chāyāharijābhyantara* literally means the distance between the *chāyā* (i.e. Rsine of the Sun's zenith distance) and the horizon. This is equal to the difference between the Rsine of the Sun's zenith distance and the radius, for the former being diminished by the Rsine of the Sun's zenith distance for midday as instructed in verse 5.

The degrees of the equator multiplied by 10 are obviously *vinâḍîs*.

The *vināḍīs* of the right ascensions of the signs could also have been defined with the help of Fig. 1. Let the arc WP (in Fig. 1) be equal to 30° (*i.e.*, the tropical longitude of the end-point of the final sign Aries), OQ, the perpendicular dropped from P on OW intersecting the circle drawn with radious Rcos δ_1, at R, and ORT, the line drawn from O through R. Then the number of degrees in the arc WT, multiplied by 10, are the *vināḍīs* of the right ascension of the first sign Aries. The *vināḍī-s* of the right ascensions of the second and third signs may also be defined similarly.

यंत्राणि

शङ्कुः

[रविक्रान्तिः]

माध्यन्दिनीसमेता नाड्यर्थे सा तया हीना || ५ ||
(शङ्क्वग्रयातसूत्राद् विषुवान्तरे या क्रान्तिरुक्ता सा) || ८ ||

ASTRONOMICAL INSTRUMENTS

Gnomon

The Sun's declination defined by means of the moving gnomon and the armillary sphere.

8. Whatever be the position of the (moving) gnomon in the path described by it (lit. in the shadow), whether at midday, or when towards the east or elsewhere, the angular distance between the equator (*viṣuvat*) and the thread that proceeds from the centre and passes through the vertex of the gnomon is called the (Sun's) declination.

[मध्याह्नच्छायातः अक्षांशः]

विन्यस्योदक् छायां छायाग्राच्छङ्कुरपरतः (पात्यः) |
तत्कर्णसमं मध्यात् प्रसारयेत् सूत्रमापरिधेः ||९ ||
तद्विषुवान्तरमक्षोऽतोऽक्षाच्चैवं प्रकल्पयेच्छायाम् |

8a. A. मध्यानां प्रांतथा; B. मध्यान्यां धातपा; C. [मध्ये विन्यस्य] तथा

b. A.B. छायायामन्य (B. ख) तो; C. छायाऽभावै स्वतो गते
A.B. गते ततः शं B. शकौ; D. शङ्कौ

c. A. यातंत्सूत्रा; B. यातत्सूत्राः C. [ख्यग्रान्तं सूत्रं]

d. A.B. विषुवान्तरयाश्र्व; C. विषुवान्तरभांशका उदिताः
A. कांद्गदिताः; B. कान्दिः दिताः (B2. °कान्द्रिदिनाः)
D. विषुवान्तरं यश्च कांक्षितम्

Local latitude (from the equinoctial midday shadow and vice versa)

9-10 (a-b). Lay off the (equinoctial midday) shadow towards the north, and let a gnomon be caused to fall to the west (or east) from the tip of the shadow. Then stretch a thread from the centre along the hypotenuse (of the gnomon triangle) up to the circumference (of the circle drawn on the ground). The (angular) distance between the point thus reached and the equinoctial point (i.e. the west or east point, whichever is nearer) is the latitude of the place. Similarly, from the latitude one may find the (equinoctial midday) shadow.

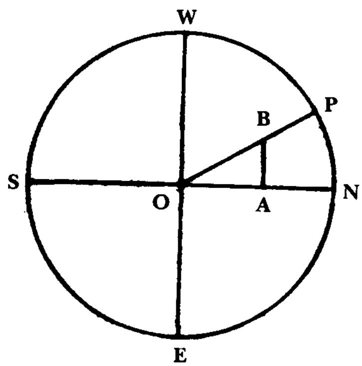


Fig. XIV.3

In Fig. 3, let ENWS be the circle drawn on level ground, E, N, W, and S being the east, north, west and south cardinal points. OA is the equinoctial midday shadow of the gnomon, AB the gnomon which is caused to fall to the west from the tip of A of the equinoctial midday shadow. OBP is the thread stretched along the hypotenuse OB up the point P on the circumference of the circle. Then, the angle PON or the arc PN is equal to the altitude of the equinoctial midday Sun, *i.e.*, the colatitude of the place, and the complementary angle POW or arc PW is equal to the zenith distance of the equinoctial midday Sun, *i.e.*, the latitude of the place.

[रेखांशः]

इष्टेऽहनि बुद्ध्वाऽपममक्षादधिकं यदूनं वा || १० ||
तज्ज्या तिर्यग्रेखा विषुवद्रेखा स्थिता स्पृशति यस्मिन् |
तच्चापांशसमानो ज्ञेयोऽर्को गोलभागेन || ११ ||

Sun's longitude

10 (c-d)-11. On the desired day find the Sun's declination, no matter whether it is greater or less than the latitude. Find the Rsine of that and insert it between the ecliptic and the equator (at right angles to the latter, in its own quadrant). The arc of the ecliptic measured eastwards from the first point of Aries up to the point where the Rsine touches the ecliptic, should be known as (the longitude of) the Sun.

9a. A.विन्यश्यो; B.विष्टभ्यश्यो (B2.विन्यं)
B.दृक् for दक् B.छाया and hapl. om of one छाया
b. A.पात्पः; B.पाताः
d. A.सूत्रं मा B2.परिधो; B1.3.एरिधो
10a. A.तद्विष्वंतरं; B.तद्विष्ठंतरं
b. A.कल्पये. B.छाया
10c. A.बुध्यायन; B.बुध्ध्ययनक्षा॰; D.बुध्वायन
d. A1.॰महादधिकं
11a. A1.तज्या; A2.तज्पा
a-b. B. Hapl om. ग्रे-खादिषु
c. B1.2.चापाश
d. B.॰मान ज्ञेयोको B.भागेना

यष्टिः

[स्फुटतिथिः]

छेद्यार्धयष्टिवेधादर्केन्द्वोरन्तरांशकार्कांशः |
स्फुटनष्टतिथिर्ज्ञेया तस्मात्कार्या तथा चान्या || १२ ||

V-Shaped Yaṣṭi

True tithi

12. One-twelfth of the degrees intervening between the Sun and Moon observed by means of a (V-shaped) Yaṣṭi of length equal to the semi-diameter of the level circle (with one arm pointed towards the Sun and the other towards the Moon) is to be known as the true *tithi* which being destroyed is to be known. From that (true *tithi*) one may derive another.

Similar rules are found to occur in Lalla's *Gola* (VIII 42-43) and Śrīpati's *Siddhānta-śekhara* (XIX 26).

[चन्द्रांशः]

दत्वांशकेषु तेष्वेव भास्करं छेद्यकेन विज्ञातम् |
स भवति तस्मिन् काले निशाकरश्छेद्यकेनैव || १३ ||

Moons longitude

13. When the Sun's longitude, obtained graphically, (vide above. vv, 10 c-d-11) is added to those degrees (intervening between the Moon and the Sun), the result is the Moon's longitude for that time. This is how the Moon's longitude is obtained graphically.

[शङ्कुच्छायातः दिगानयनम्]

नाभ्याः शङ्कुच्छायाग्रमङ्कयेत् त्रिस्ततो लिखेन्मत्स्यौ |
तन्मत्स्यवदननिःसृतसूत्रद्वयपातमध्येन || १४ ||

12a. A. छेद्यर्ध; B. छेद्यद्य; C. केन्द्रार्ध
b B. दकेद्वोरंत्वशशवतकाशिः |
c. A. तिथिशेया
d. A2. चान्पा

13a. A. ०केपु; B1.2. read: द चंशकेषु (B2. अंचंशकेषु) B3. दचंशकेषु
b. B. भास्करछेद्यकेन
c. A.B1. भवति हि तस्मिन्
d. A. ०करात् छिद्यं; B. ०कर—य (B2.3. ध) केनैव

(सूत्रेण) बिन्दुकत्रयसंस्पर्शसमेन मण्डलं यत् स्यात् |
तेन तदह्निच्छाया शङ्कोर्गच्छत्यमुञ्चन्ती || १५ ||

तन्मण्डलमध्यं यच्छङ्कुतश्च दक्षिणोत्तरं भवति |
तच्छङ्कुविवरमुदगास्थितं च माध्यन्दिनी छाया || १६ ||

Cardinal directions (by means of three shadows of a gnomon)

14-16. Mark three times (at intervals) the tip of the shadow of a gnomon set up at the centre of the circle (drawn on level ground). With the help of those (three points) construct two fishes. Taking the point of intersection of the two strings passing through the head and tail of those fishes as centre and a thread so long as to touch the three points as radius, construct a circle (passing through the three points). The tip of the shadow of the gnomon that day moves on that circle without swerving from it.

16. The centre of that circle lies to the north or south of the gnomon. Between that and the gnomon is the midday shadow lying to the north (or south) of the gnomon.

The midday shadow falls towards the north or south according as the Sun's northern declination δ is less or greater than the latitude ϕ of the place. When the Sun's declination is south, the shadow always falls towards the north.

[खगोलः]

हरिजमिति गगनमवनौ प्रसक्तमिव यत् प्रदृश्यतेऽन्तेषु |
सममिति पूर्वापरतो ह्येवमेव दक्षिणोत्तरतः || १७ ||

ध्रुवहरिजविवरमक्षोऽक्षनवतिविवरं च लम्बकोऽभिहितः |
(लम्बो)नमति ख(मध्याद्) द्युव्यासोऽस्तोदयाख्यस्य || १८ ||

The Celestial Sphere

17. (The circle) where the sky appears to meet the earth at their skirts is called the horizon (*harija*). The (vertical) circle which runs from east to west is called

14a. A.B. नाभ्यासंन छा (B2. च्छा) याग्रं (A. ॰छाद्या); D. नाभ्यासन्नच्छायाग्र॰
b. B1. ॰ग्रंनकये (B2. न कपे-त्रिसुतो)
c. B. मत्स्यव - निसृतसूत्रं द्वय
d. A.B.C.D. तुल्येन

15a. A. सूर्येण; B. स्तार्येण
c. B1. तिन for तेन
D. तदाह्नि छाया; B. तदह्नि छाया

16a. A. मध्या; B. मध्यात्; D. मध्याधश्छङ्कु;
b. A. छंकुः श्च B3. छङ्क. B. दक्षिणोत्तरे
c. A. तछंकु; B. तछजषविवर
d. B. ॰गास्थितश्च

the prime vertical (*samamaṇḍala*). Similarly, the (vertical) circle which runs north to south is called the meridian (*dakṣiṇottara*)

18. The (arcual) distance between the north pole and the horizon is called the latitude (of the place). The difference between 90° and the latitude is called the colatitude. The colatitude is the depression (of the north pole) from the zenith. The day-diameter is the diameter of the so called diurnal circle (*astodayākhya*).

[अर्धकपालयंत्रम्]

छेद्यवदर्धकपालं सचिन्हमक्षोन्नतं सदिक्चक्रम् ।
सुसमावटविन्यस्तं कुर्याच्छङ्कुं सनाभ्यङ्कम् ॥ १९ ॥
सूत्रद्वयसम्पातच्छाया [भुजांशका] रवौ देयाः ।
स भवत्युदयो राशिर्दिनस्य नाड्यश्च [षड्भक्ताः] ॥ २० ॥

Hemispherical Bowl and its use

19. Construct a hemispherical bowl of the radius chosen for our constructions with a gnomon fitted at its centre. Graduate its circular rim with marks of cardinal directions and circular divisions (signs and degrees etc.). Place it in a smooth (hemispherical) cavity in the ground with the gnomon inclined to the horizon at an angle equal to the latitude of the place (and pointing to the north pole).

20. Read the degrees traversed since sunrise by the shadow (of the gnomon) which passes through the intersection of the two lines (*viz.*, east-west and north-south), and add them to the Sun's longitude. The sum thus obtained is the longitude of the rising point of the ecliptic. The degrees crossed over by the shadow divided by six are the *nāḍīs* of the day (elapsed since sunrise).

17a. A.B. हरियमिति B. गमतेमवनौ
b. A1. प्रदृश्यंते तेषु; B1. प्रदिश्यन्तेषु (B3. ॰न्तेवु)
c.d. A. ह्येवमृगं दक्षि; B. परतो येव मृणं दक्षि; C. ह्येवमतो दक्षि D. परेरेखैवं च दक्षि
d. B1.3. ॰त्तरगत; B2. ॰त्तरत; D. ॰त्तर गता

18a. B. हिरेज
A-B. विवरमक्षः
b. A. क्षितिरवदिविवरं; B. क्षिभिरवविकिंवर च
B. ॰भिगृह्वितः
c. A.B.D. लग्नो (B. मणो) नमिति
A.B. खमध्य; D. खमध्यं

d. A. स्तोदय ॥; B. स्तो— ॥;
D. स्तोदय [चक्रस्य]

19a. B. ॰वदर्ह्य D. ॰वदर्ध्यकपालं
b. B. स (B3. ख) चिड्ड [B2. द्रु] मक्षौत्र च स दिक्॰
c. B. सु (B3. स) यवाढ (B3. रु) विन्यस्तं (B3. स्त)
C. सुसमावनिविन्यस्तं
d. A.B. कुर्यादिक्कः (B1.2. क B3. ख)
A.B. सनाभ्यंकं (B. कुं)

20a. B2. खम्पात; D. सम्पाता
b. A.B. मुक्ताशका; C.D. भुक्तांशका
c. B. राशिर्दिनाड्यस्य
d. A.B.C.D. नाड्यश्च ता याताः (B. यातः)

[चक्रयंत्रम्]

समभगणांशकचक्रमर्धाङ्गुलबहलमायतं हस्तम् |
विस्तारमध्यभागे छिद्रं तद्गामि तिर्यक् च || २१ ||
मध्याह्नार्कमयूखं प्रवेश्य सूक्ष्मेण परिधिविवरेण |
मध्यावलम्बिसूत्रात् तदान्तरांशा (स्तदा खाक्षः) || २२ ||

Hoop and it use

21. Construct a circular hoop with diameter equal to one cubit (= 24 digits) and rim half a digit broad. Graduate its (inner) rim evenly with the marks of signs and degrees (etc). At one place in the middle of its broad rim, pierce a fine hole at right angles to the rim.

22. When it is noon, let a ray of the Sun pass through the fine hole in the rim (and fall on the diametrically opposite point of the rim). The degrees that lie between the thread hanging vertically through the centre and that (ray of light) indicate the Sun's meridian zenith distance.

The word *khākṣa* is a technical term used in Indian astronomy in the sense of "meridian zenith distance". Also see *supra*, IV. 21, where the same term has been used in the same sense.

[गोलबन्धः]

समवृत्तपृष्ठमानं सूक्ष्मं गोलं प्रसाध्य धातुमयम् |
स्थगितार्कसमाङ्कितकालभोगरेखाद्वये परिधौ || २३ ||

Armillary Sphere

23. Construct a perfectly round light (Armillary) Sphere by means of wooden strips (or metallic spokes). On the surface construct two circles, one representing the equator (*kāla-rekhā*) and the other the ecliptic (*bhoga-rekhā*) being marks where the Sun stops (*i.e.* at the two solstices).

21a. A.°भगणांकक°; B.भगणांफक° B.वक्र for चक्रं
b.˜ B1.3.मर्द्धगुलवदजम त हं A.वहल B.हस्त
c-d. B.छिद्रं ---
d. A.B.तिर्यक्का

22a. B.मध्याद्धा (B2.ह्ना) र्का A.मयूषं; B.मसूष
b. B.विचरेण; D. [विचरणेन]
c-d. A.सूत्रांतलांतरांश°; B.सूत्रान्तल्पान्तरांश° C.सूत्रात् तलान्तरांश°; D.सूत्रातप्तान्तरांश°
d. A.तदन्पक्षः; B.तदन्यक्षम्; C.D.तदन्याक्षः

23a. A.पृष्टमानं; B.षष्ट (B2.षष्ठ) मानं
b. B.शूक्ष्मं (B3.सूक्ष्मं) प्रसाध B.C.D.दारुमयं; A2.धानुमयं
c. A.स्थगितार्कमङ्कित; B.स्थगिचावर्मिकित; D.स्थगितार्कसमङ्कित

याम्योदग्रेखायां झषाजसंध्युभयतो न्यसेद्वेधात् |
अपमांशकाङ्कतुल्यांस्तिर्यगृवेधप्रकाशकरान् || २४ ||
अक्षोत्क्षिप्तस्योदक् तिर्यगृवेधप्रकाशहरिजस्थाः |
या नाड्यस्ता याता षडंशकसमन्विता मध्ये || २५ ||

24. On either side of the junction of Pisces and Aries, in the north-south (hour) circles at points denoting the degrees of the (Sun's) declination, fasten, by means of observation, light points which may illumine the (Sun's) oblique diurnal circles.

25. Mount the (Armillary) Sphere in such a way that it is elevated towards the north by an amount equal to the local latitude. Then the *nāḍīs* that lie (on the Sun's diurnal circle) between the light point on the (Sun's) oblique diurnal circle and the horizon denote the *nāḍīs* that have elapsed (since sunrise in the forenoon), each *nāḍī* being made up of six degrees.

[रवेः उत्तर-दक्षिणगती]

यदुपेति कालचक्रे मृगादिकमुद[गयनं]द्युवृद्धिः स्यात् |
व्यत्यासे तद्धानिर्व्याख्यातात्छेषमिति गम्यम् || २६ ||

Sun's northward and southward journeys

26. In the cycle of time, as long as the Sun is in the six signs beginning with Capricorn, it is Uttrāyaṇa (i.e. the period of the Sun's northward journey) and there is increase of day; in the contrary case (i.e., when the Sun is in the six signs beginning with Cancer), there is decrease of day. What remains to be said (here) is to be understood from what has already been stated.

24a-b. B. रेखायाश्चरवाजसन्ध्याभयसो
b. A2. न्यमेत् B1.3. वेधम्; C. वेधान्
c. A.B.D. अयर्नांश॰
B. ॰काक तुल्या (A2. नुल्या);
d. B. तिर्यग्वैद्यप्र॰;
A2. करात्; B. कारान्
25a-b. A. अक्षोक्षिप्त॰; B. अक्षौक्षिपूष्पोदक्
(B3. पूयिनोशकाकन्येस्योदक्)
b. B. जास्थाः
c. A. यान्याड्यः; B3. Scribe omits unknowingly three lines: या [नाड्य to गुण] सलिल, 27a.
d. A.B. समिन्वताः
26a. A.C.D. यदुदयति
b. A. भागादिक॰; B. भादिक॰; C. प्रागादिक॰
A.B.C. मुदयते; D. मुद [गयने]
B. तेषु वृद्धिः सा |
c. A. तद्धाति व्या; B. तद्धानिव्या॰
d. A1. ॰मितिम्य॰; A2. ॰मिति-म्य॰; B. om गम्यम्

[कालमानयंत्राणि]

गुणसलिलपांशुभिर्योजितानि बीजानि सर्वयंत्राणाम् |
तैः फलके कूर्ममानवयथेष्टरूपाणि कार्याणि || २७ ||
गुरुरचपलाय दद्याच्छिष्यायैतान्यवाप्य शिष्योऽपि |
पुत्रेणाऽप्यज्ञातं बीजं संयोजयेद् यंत्रे ||२८ ||

Instruments for measuring time

27. The *bījas* (i.e. seeds or basic necessities) of all instruments (for measuring time) are furnished by string, water and sand[1]. By means of them one may construct instruments resembling a tortoise, a man, or any other desired shape, and mount them on a wooden board.

28. The teacher should impart (this knowledge) only to a devoted (lit. steadfast) pupil, and the pupil too, after having learnt it, should apply the *bījas* (string, water and sand) to his instruments, keeping the secret unknown to his son even.

Varāhamihira has not described these instruments here only to keep their mystery a secret. But these instruments have been described in some of the later works. For example, see the chapter on astronomical instruments in the works of Lalla and Śrīpati. But there too the description is not very explicit.

[देशान्तरम्]

अभिमतदेशाक्षवशात् कृतवेधेनेन्दुपूर्णिमाकर्म |
दृष्टिघटिकोदयांशानधिकाल्पत्वे वियुतयुतम् || २९ ||
तिथिवद्विभज्य लब्धं चरकालेनान्वितं क्रियाद्येषु |
जूकादिषु च विहीनं विषुवति देशान्तरं स्पष्टम् || ३० ||

Local longitude in terms of time

29. By means of observation at the desired place in a given latitude, perform the Moon's *pūrṇimāntakarma* (i.e. find out how much time after or before local sunset the Moon rises at the local place). The degrees of the ecliptic which rise during that time should be subtracted from or added to the Moon's longitude according as the Moon rises later or earlier than sunset.

27a. A.B.गुणं
b. A.वीजानि B.योजातानि
c. B1.3.कूर्म्म; B2.कूर्म्य
d. A2.०ष्टरु । पाणि

28a-b. A.चपालाय; B.गुरुख्रपल (B2.०पदेले) —दद्या०
A.दद्याछि०
c. A1.०प्यज्ञानं
d. A.वीजं
B.संयोजये-नो ||

1. When a heavier substance than sand was required, Mercury was used.

30. Dividing as in the case of *tithi*, find the local time in terms of *ghaṭīs* for the end of full moon *tithi* (as reckoned from local sunset). Increase or diminish the *ghaṭīs* obtained by the time corresponding to the Sun's ascensional difference, according as the Sun is the six signs beginning with Aries or in the six signs beginning with Libra. The result is the local time for the end of the full moon *tithi* at the local equatorial place. (The difference of this and the local time for the end of the full moon *tithi* at Laṅkā) is the true longitude for the local place.

The rule is obvious, because: (a) Local time for the end of the full moon *tithi* at the local place (as measured since sunset at the local place) ± time corresponding to the Sun's ascensional difference = local time for the end of the full moon *tithi* at the local place (as measured since sunset at the local equatorial place),

+ − sign are to be taken according as the Sun is in the six signs beginning with Aries or in the six signs beginning with Libra.

(b) Also, local time for the end of the full moon *tithi* at the local equatorial place ~ local time for the end of the full moon *tithi* at Laṅkā = local longitude in terms of time.

The local time for the end of the full moon *tithi* at the local place has to be obtained by the process of successive approximations, but the whole process has not been described in the text.

[नाडी (घटी) मानम्]

द्युनिशिविनिःसृततोयादिष्टच्छिद्रेण षष्टिभागो यः |
सा नाडी (स्वमथो) वा श्वासाशीतिः शतं पुंसः || ३१ ||

कुम्भार्धाकारं ताम्रं पात्रं कार्यं मूले छिद्रं
स्वच्छे तोये कुण्डे न्यस्तं तस्मिन् पूर्णे नाडी स्यात् |
मूलाल्पत्वाद्वेधो वा षष्टिर्योज्या चाह्ना रात्र्या
वर्णाः षष्टिर्वक्राः श्लोको यत्तत् षष्ट्या वा सा स्यात् || ३२ ||

8. The Nāḍī or Ghaṭī

31. One-sixtieth of the time taken by water to flow out through a desired hole during a nychthemeron is defined as the duration of a *nāḍī*. Or, it is the time of 180 breaths of a man.

29a-b. B. देशाक्षतवशाक्षतपधेनोदुप्तरामिकर्मा;
A. कृतवधेनोडुपूर्णमाकर्म; D. कृतवेधेनोडुपपूर्णमाकर्म
c. B. देष्टि
c-d. A.B. घाटिकोदयांसंदुत्पान्यत्वे; (B. °स तुल्यान्यत्वे);
C. घटिकान्तरांशानधिकाल्पत्वे;
D. घटिकोदयांशतुल्यान्यत्वे
d. A.C.D. वियुतयुक्तं; B. विड्युत (B2. विधुत) युक्तं
30a. B. तिथिवधिभाज्यं D. विकृत्य
b. A. चकालादिनान्वित°; B. चकालदनान्वितं
c. A.B. जूकादिषु पति हीनं
d. B. विषुवती

32. Construct a copper vessel resembling one-half of a spherical pot and pierce a hole at its bottom. Put it in pure water in a basin. The time in which the vessel is filled up is the duration of a *nāḍī.* The hole at the bottom of the vessel should be so small that on account of its small size, the vessel may sink into water exactly sixty times during nychthemeron. Or, it is the time in which one may recite 60 times a verse composed of 60 long syllables (as vs. 32 is).

[शशितारायोगः]

बुध्वा शशिविक्षेपं दृष्ट्वा ताराशशाङ्कविवरं च |
संसाध्यैवं वाच्यः पश्चात्तारासमायोगः || ३३ ||

Conjunction of the Moon with a Star

33. Having ascertained the Moon's celestial latitude and observed the distance of the Moon from a star and having made the requisite calculations, one should predict the time of conjunction of (the Moon with) the star which is to take place in the future.

[नक्षत्रस्थानानि]

बहुला षष्ठांशान्ते सार्द्धे हस्तत्रये च भगणोदक् |
रोहिण्यष्टदलान्ते दक्षिणतश्चार्द्धषष्ठेषु || ३४ ||

हस्तेष्टऽमेऽष्टमेंऽशे पुनर्वसोर्दक्षिणोत्तरे तारे |
अर्द्धचतुर्थे हस्ते पुष्यस्योदक् चतुर्थेऽशे || ३५ ||

31a. B. घुनिशि. A. विनिसृतं; B. विनिसृत
b. A.B. तोय दिष्ट छिद्रेण
c. B1.3. स्वतचो; B2. स्वमन्नो; D. स्वमता
d. A.B. स्वासाशीतसमं. B. घुसः
32a. B1.3. कुम्भाद्विकारं; B2. कुम्भार्द्रकारं B. मुले
B1.3. छिरं
b. A. स्वछे; B. स्वच्छे—तोये
B. क्रुडे न्यस्ते
B. पुर्सो नाडी
c. D. मूला पातात्
A.B. षष्ठिजोज्यामन्हा (B. न्द्रा) रात्र्या
d. A.B. षष्टिवक्त्राः
A1. यत्ततष्ट्या वा; A2. यत्रत्षष्ट्या
A. साम्यात्

33. Quoted by Utpala on *BS* 24.5-6.
a. U. कृत्वा
B. After बुध्वा occurs the passage ति हेतुः (of XV. 8) to सः || अ (of XV. 23), being transferred here, apparently due to the misplacement of a folio in the common archetype of the B mss., B1,2 and 3.
B. राशिविक्षेपं
b. B. नाराशशाङ्क
c. A. संसाध्यैव वाच्यः; B. संसाध्यैव—वाच्यः;
U. संसाध्य च वक्तव्यः

दक्षिणतारा हस्ते सार्पस्यांशे तथोत्तरा तारा |
पित्र्यस्य स्वक्षेत्रे षष्ठे चांशे समायोगः || ३६ ||

चित्रार्धाष्टमभागे दक्षिणतः संस्थिते त्रिभिर्हस्तैः |
विक्षेपकलान्तादङ्गुलानि मध्याच्छशाङ्कस्य || ३७ ||

Positions of Certain Junction-Stars

34. (The junction-star of) Kṛttikā is at the end of the sixth degree (from the initial point of that *nakṣatra*) and 3½ cubits to the north of the ecliptic. (The junction-star of) Rohiṇī is at the end of the eighth degree (of that *nakṣatra*) and 5½ (cubits) to the south.

35. The southern and northern (junction-) stars of Punarvasu are at the end of the eighth degree (of the *nakṣatra*) and 8 (cubits) south and north (respectively). The (junction-)star of Puṣya is at the end of the fourth degree (of that *nakṣatra*) and 3½ cubits to the north.

36. The southern (junction-) star of Āśleṣā is at the end of the first degree (of that *nakṣatra*) and one cubit (to the south); so also is the northern (junction-star). The conjunction (of the Moon) (with the junction-star of) Maghā occurs in its own field at the end of the sixth degree (of that *nakṣatra*).

37. (The junction-star of) Citra is at the end of 7½ degrees (of that *nakṣatra*) and 3 cubits to the south. The digits are counted from the centre of the Moon where the minutes of the latitude end.

[शशितारयोरङ्गुलमानम् योगकालश्च]

विक्षेपात्सप्तदशापनीय तिथिसङ्गुणात् कृताग्न्यंशः |
विद्यादङ्गुलमानं कालं दिनभोगविवरेण || ३८ ||

Digits between the Moon and a Star in Conjunction

And Time of Conjunction

38. Having subtracted 17 from the latitude (of the star with respect to the Moon) multiply by 15 and take a thirty-fourth of that; this is to be known as the number of digits (between the Moon and the star).

34a. B.चन्द्रला; D.बहुलाः
A.षष्ठांशात्ते; B.षष्टाशाति; B2.हातं
b. A.भगणोदक; B.भगणोदकः
c. A.दलात्ते
d. A.B.दक्षिणस्तश्च A.स्वार्ध; B.स्वार्द्धे;
A.षष्टेषु

35a. B.॰मेऽष्टमेशे
b. A.B.D.पुनर्वसौ दक्षि
c. A2.तरे for तारे B.हस्तेषु पुष्य
d. A.॰स्पोदक् A.चतुर्थेशे
36a. A.सार्प्यस्पांसेत्तथोत्तरात्तारा
c. A. पित्र्यस्य स्त्रछेत्रे; B. स्वष्टे च त्रे
d. A.B.षष्टे A.वांशे; B.वाशे

37a. A.चित्रार्धाश्रमभागे
b. B.त्रिहस्तैः
c. A.कलात्तादंगु; B.कलीतादृगु
d. A.मध्याछशां; B.मध्याछः शकस्य

The time (of conjunction) is to be known from the distance between the star and the Moon and the daily motion of the Moon.

According to Varāhamihira, the measure of the Moon's diameter is 34 in terms of minutes and 15 in terms of digits. Hence the above rule.

Polar longitudes and latitudes of the Junction-stars

Junction-star of	Polar longitude	Polar latitude
Kṛttikā	32°40′	3.5 cubits or 3° 10′ 24′N
Rohiṇī	48°	5.5 cubits or 4° 59′ 12″S
Punarvasu (southern)	88°	8 cubits or 7° 15′ 12″ S
Punarvasu (northern)	88°	8 cubits or 7° 15° 12″ N
Puṣya	97° 20′	3.5 cubits or 3° 10′ 24″ N
Āśleṣā (southern)	107° 40′	1 cubit or 54′ 24″ S
Āśleṣā (northern)	107° 40′	1 cubit or 54′ 24″ N
Maghā	126°	0
Citrā	180° 50′	3 cubits or 2° 43′ 12″ S

[अगस्त्योदयः]

विषुवच्छायार्धगुणा पञ्चकृति(स्तिथियुतं) ततश्चापम् |
छायात्रिसप्तकयुतं दशभिर्गुणितं विनाड्यस्ताः || ३९ ||
ताभिः कर्कटकाद्याद्यल्लग्नं तादृशे सहस्रांशौ |
याम्याशावनितामुखविशेषतिलको मुनिरगत्स्यः || ४० ||
गणितविषयोपलब्धच्छेद्यकयंत्रैः प्रकाशतां याति |
सुखयति मनांसि पुंसां दिव्यं कालाश्रयं ज्ञानम् || ४१ ||

Heliacal Rising of Canopus

39. Multiply the square of 5(i.e. 25) by half the equinoctial midday shadow; (treating it as the Rsine of an arc) find the corresponding arc (in terms of degrees) and add 15 (degrees) to that. Multiply that by 10 and add 21 times the equinoctial midday shadow. These are *vināḍīs*.

38a. B.॰दशापनीय
b. Ă.संगुणाकृता
c. A.॰माणं
A.B.भोगेविरेण (B.॰चिरेण);

39-40 Quoted by Utpala on *BS* 12.21
39a. A.विषुवछाया B.द्विगुणा
b. A.B.पंचकृतेस्तत्कलास्तत॰; D.पञ्चकृतिस्तत्कला ततः
c. A.छायानृसप्तक॰; B.छायातृप्तक A1.युत
d. A.B.गुणिता

40-41. Assuming these *vināḍīs* as the time elapsed since sunrise and taking the Sun at the first point of Cancer, calculate the longitude of the rising point of the ecliptic. When (the longitude of) the Sun happens to be equal to that, then, by virtue of the graphical methods and instruments available to the science of mathematical astronomy, the sage Agastya (*i.e.* the star Canopus) that looks like the special red tilaka-mark on the forehead of the lady-like southern direction shines forth and delights the minds of men. Such is the divine knowledge based on time.

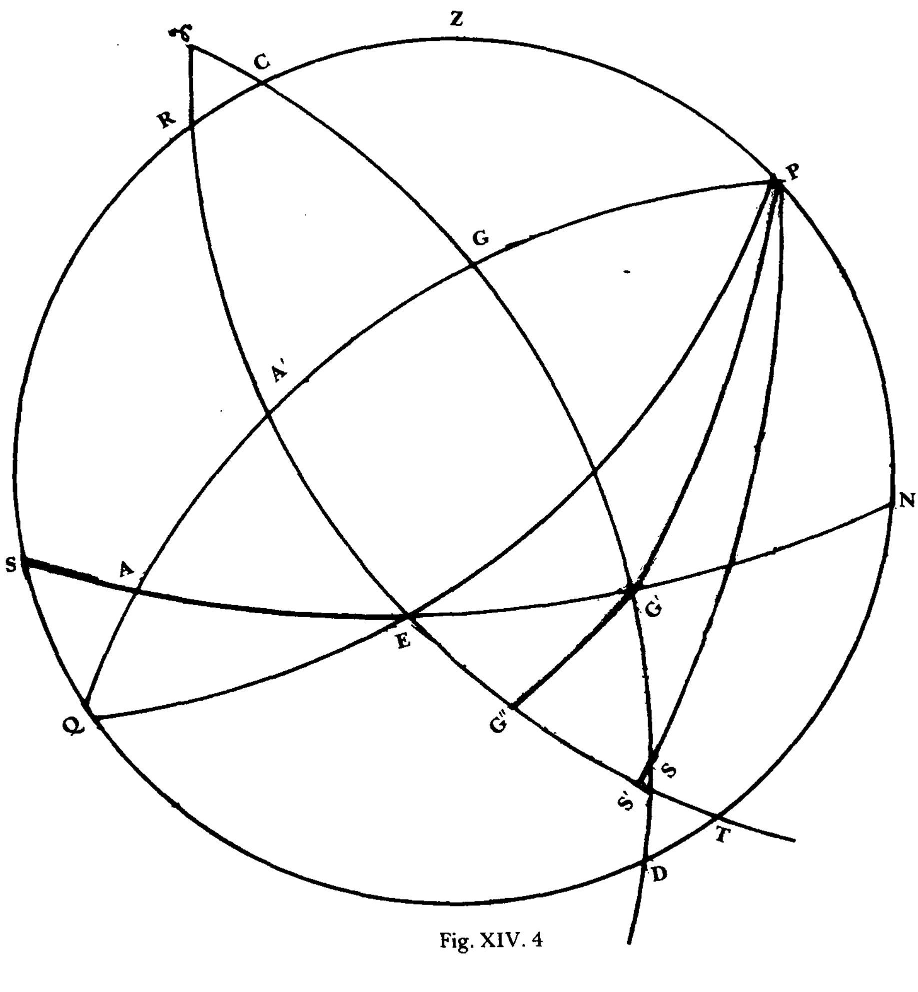


Fig. XIV. 4

Consider Fig. 4. It represents the celestial sphere for a place in latitude ϕ. SEN is the horizon and Z the zenith; ♈RET is the equator and P and Q are its north and south poles; ♋GSD is the ecliptic.

40a. A1.B.काद्यायगग्नं (B3.काङ्गाप) D.याम्यातो वनिता 41a-b. B.॰पलब्धः छेद्यकं (B2.क)
b. B1.तदशे; B2.तदंशो; B3.तदृशो B.सहस्तांशो d. A.स्नुख; B.स्तुख B.विषतिल्को b. B.प्रकाशना पातम् | B.यातं
c. A.B.याम्यास्ता (B.त्ता) वनिता; A.मुनिणस्त्यः c. B.खसुखपति

A is Canopus at the time of its heliacal rising and S the Sun at that time. PGAQ is the hour circle of Canopus, and G the point where it intersects the ecliptic.

Assuming that the celestial longitude of Canopus is 90° and the celestial latitude 75° 20′ S[1], we have ♈G = 90°, AG = 75° 20′ and AA′ = 75° 20′ − 24° = 51° 20′. Therefore

Rsin A′ E = Rsin (asc. diff. of Canopus A) = Rtan δ tan ϕ, vide formula (2),

where δ is the declination AA′ of Canopus and ϕ the latitude of the place,

$$= \frac{\sin\delta \, . \sin\phi}{\cos\phi} \times \frac{R}{\cos\delta}$$

$$= \frac{\sin 51°20' \; palabh\bar{a}}{12} \times \frac{120}{\cos 51°20'}$$

because, according to Varāhamihira, R = 120′

$$= 25 \times \frac{palabh\bar{a}}{2}, \text{ approx.}$$

∴ A′E = arc (in terms of degrees) corresponding to Rsine equal to

$$25 \times \frac{palabh\bar{a}}{2}, \text{ approx.}$$

EG″ = asc. diff. of G, approx.

= 21 × *palabhā, vināḍīs*, approx.

because for unit *palabhā*, the ascensional difference for G (the first point of Cancer) is 21 *vināḍīs*.

Also, assuming 15 to be the time-degrees for the visibility of Canopus,

G′S = G″S′ approx.

= 15 degrees, approx.

∴ A′S′ = A′E + EG″ + G″S′ degrees

= [10 (A′E + 15) + 21 *palabhā*] *vināḍīs*,

where A′E + 15 is in degrees and *palabhā* in digits. Degrees multiplied by 10 are *vināḍīs*.

Now GS is the arc of the ecliptic which rises above the horizon (of Laṅkā) in the time given by the arc A′S′ of the equator. Hence it is obvious that Canopus A will rise heliacally when the Sun is at S, *i.e.*, when

Sun's longitude = longitude of G + arc GS
= longitude of G (*i.e.*, 90°) + arc of the ecliptic which rises (at Laṅkā) in the time given by the arc A′S′ of the equator.

1. Actually, the longitude of Canopus is 85°4′ and the latitude of Canopus is 75°50′S.

Hence the rule.

Obviously, the rule is very crude. It was discarded by the later astronomers who replaced it by better rules.

[इति पञ्चसिद्धान्तिकायां वराहमिहिरविरचितायां
छेद्यकयंत्राणि नाम चतुर्दशोऽध्यायः ||][1]

Thus ends Chapter Fourteen entitled 'Graphical Methods and Astronomical Instruments' in the Pañcasiddhāntikā composed by Varāhamihira

1. A. छेदकयंत्राणि चतुर्दशोऽध्यायः |
B.D. इति छेद्यके यंत्राणि चतुर्दशोऽध्यायः |
C. इति छेद्यकयंत्राणि नाम चतुर्दशोऽध्यायः |

Chapter Fifteen

SECRETS OF ASTRONOMY

पञ्चदशोऽध्यायः

ज्यौतिषोपनिषत्

[ग्रहणम्]

सूर्येन्दुभगणधात्रीसंस्थानविदोऽधिकृत्य कथयामि |
ग्रह(णं) सदैव भानोः स्थानविशेषात् क्वचिद्दृश्यम् || १ ||

अविदितसंस्थानानां बोधोऽपि हि जायते यथाऽऽधान्याम् |
क्षीरं शंखोपहितं द(श)नविनाशक्षमं भवति || २ ||

Eclipses

1. I declare the following to those who possess pre-knowledge of the relative positions of the Sun, the Moon, the zodiac with the principal stars, and the earth. There is always an eclipse of the Sun visible somewhere in space, according to the position of the place.

This is what is meant: If a solar eclipse is defined as being caused by the Moon hiding the Sun, it is obvious that at any moment some place in space will have the Sun hidden behind the Moon.

2. For those who do not know the relative positions of the above mentioned, even knowledge will become similar to the milk in the container with conch in it becoming capable of destroying the teeth.

This is the meaning:- Milk and Conch are by themselves beneficial things, especially conch which can strengthen the teeth on account of its calcium content. But milk with conch soaked in it becomes positively harmful to the teeth on account of their incompatibility. So also, even knowledge can become harmful unless the knowledge as to when, where and how to use it is also known.

TS have amended the correct *dhānyām* into *dhānyam*, not realising that the word intended in the context is *ādhānī*, meaning the vessel for holding the milk, and also not understanding what is meant by the verse. For similar reasons, NP have emended the word as *dhyānāt*, and gives a meaning opposite to what is intended by VM.

1a. A. भगणा B. धात्रीं
c. Ă. ग्रहाणां
d. B. विशेषात्त
A. क्वचिदृश्यं; B. कचिदृश्यम् (B3. कवि)

2a. B1.3. आअविदित A. सस्थानानां; B. सस्तानानां
b. B. वेद्योपि B3. तायते
B. ध्यान्याम्; C. यथा ध्यानम्; D. यथा ध्यानात्
c. A. दशान; B1.3. दशानन; B2. दशा विना

संक्षेपसू(त्रवशतः) शशिना(ऽऽव्रि)यते दिवाकरो येषाम् |
तेषां सूर्यग्रहणं स (च) देशः प्रतिदिनं क्वापि || ३ ||

सकृदेव रविं ग्रस्तं पक्षं पश्यन्ति शशिगताः पितरः |
अग्रस्तमपि च पक्षं ग्रहमध्यं पौर्णमास्यां तु || ४ ||

3. For these to whom the Sun is hidden by the Moon, according to the straight line from them through the Moon touching the Sun, for them there is a solar eclipse. And every moment (lit. every day) there is such a place somewhere.

4. The pitṛs (Manes) on the Moon see the Sun eclipsed for one whole fortnight, and not eclipsed during the other fortnight. The mid-eclipse is at full moon.

Fig. XV.1. (diagrammatic, not to scale)
P: The Pitṛs on the moon
M_1: Position of moon at middle of dark fortnight.
M_2: New moon position
M_3: Position at middle light fortnight
M_4: Position at full moon
On the side facing the sun, the Moon has sunlight. On the other side it is darkness.

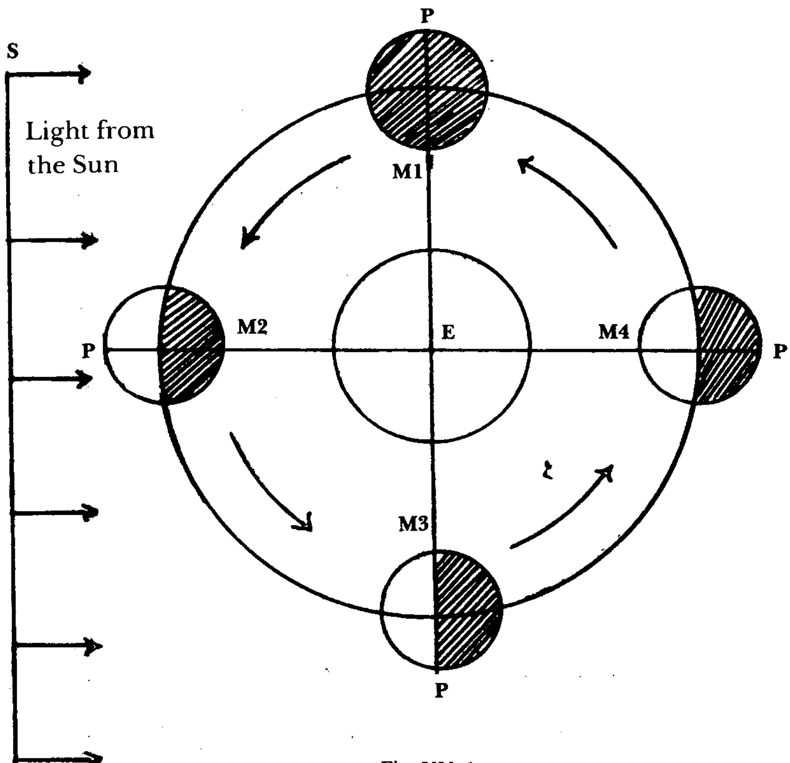


Fig. XV. 1

3a. A2. संक्षेपा A.B. सूत्रावशशिना (B. सूत्रावं); D. सूत्राविशेषेण
b. A.B. त्रियते; C. ध्रियते; D. तीर्यते
c. B. Hapl. om of तेषां
d. A. स व देशः

4a. B. रविग्रस्तं
b. B3. पितराः
c. A. अग्रस्य B. °मवि च
d. B. ग्रस्तं मध्या A. मध्य

At M_1 position P (Pitṛs) just begin to get sunlight. It is sunrise to them. At M_2 it is midday, with Sun abovehead. At M_3 daylight ends and darkness begins. At M_4, it is midnight for the Pitṛs. On the earth, M_2 is new moon, M_3 mid-light fortnight, M_4 is full moon, and M_1mid-dark fortnight. Thus, full moon on earth is midnight for the Pitṛs, the whole night being the eclipsed time.

Note that the Pitṛs are supposed to dwell in the region opposite, along the line of sight of the Moon. Note also that the synodic month forms the whole day for the Pitṛs, full moon being midnight and new moon being mid-day. Note again that the explanation above can hold good only if the Moon shows the same face to the Sun, as it really does. The Hindu astronomers held the same view, without any conception of it, for they held this view in the case of every planet. TS are confused, not keeping in mind clearly that the month for us is the day for the Pitṛs. Here, *graha* means eclipse, and really there is no difficulty, which they seem to feel.

न कदाचिदपि ग्रहणं मेरुगता मेरुसन्निकृष्टा वा |
पश्यन्ति तिग्मरश्मेः अनुच्चभावाद्रविहिमांश्वोः || ५ ||
अर्केन्दुदृष्टिवेधो न मेरुगा[नां] कदाचिदपि [भवति] |
पार्श्वस्थास्ते विवरं पश्यन्ति सदैव सूर्येन्द्वोः || ६ ||

5. People at the North-polar region never see a solar eclipse occurring, because of the Sun and the Moon never being high enough in the sky.

6. The Sun and the Moon can never be in a straight line with the eye for people in the North-polar region. Being on the side (as viewed from the region of low latitudes) they always view a gap between the Sun and the Moon.

V.M. is wrong here. Every general partial eclipse, and some total or annular eclipses also, are visible even at the pole. Though the Moon's parallax will be near maximum, with a high enough celestial latitude, the Moon can be projected on the Sun to form an eclipse. If VM had worked out an example, he would have discovered his mistake. He seems to have been misled by the fact that eclipses visible in low latitudes like India, would not be visible in the polar region. TS too say VM is wrong.

Prosody requires some additional *mātrās* in (6), and I have added *nām* and *bhavati* in the second foot. TS's emendations which are adopted also by NP, do too much violence to the text.

यद्य(प्यु)दयेऽस्ते वा (नी)चस्थोऽस्माकमंशुमा(न् भ)वति |
च(न्द्रः) पर(मुच्च)स्थः घन(व)द्भानोर्भवति हेतुः || ७ ||

5b. B. सन्निधिकृष्टा
d. B. अनुश्वभाद्रविहमांशोः (A.B. मेरुगा; A. पाश्र्वं)
6a. C. दृष्टिवेधं; D. दृष्टिवेधा
b. A.B.C.D. ने मेरुगाः कदाचिदपि पार्श्वस्थाः |
c. C.D. ते [सर्वे खलु] विवरं
d. B. सूर्येन्दोः

7. Though the Sun is low near the horizon, near sunrise or sunset, the Moon, being higher up, can hide the Sun like a cloud.

VM here answers an objector to his stand (5-6). He is unaware that the case in (7) is similar to that (5-6).

TS's emendations *paramocca*, which means 'standing high up in the sky', will make an eclipse itself impossible. NP's emendation *candroparasamavastha* does not give the sense of 'being under the Moon' given by them for the expression.

अस्माकमुदयसमये येषामल्पास्तगो दिवसनाथः |
मध्याह्नो वा येषां तेषामपि न युगपद्ग्रहणम् || ८ ||
तदतीतमुदयगानां क्षणद्वये (नैष्य)दस्त(देशा)नाम् |
मध्याह्नदे(श)गानामनवरतं वर्तमानेन || ९ ||

8. For people who have sunset and for people who have mid-day, when we have sunrise, for all of us, the solar eclipse does not occur at the same time.

9. Throughout the time when there is eclipse for the mid-day people, it is past for the sunrise people by four *nāḍikās,* and will be yet to occur for the sunset people by four *nāḍikās.*

The context is the solar eclipse and the Moon is near the Sun, So for the sunrise people the apparent longitude of the Moon has increased by parallax, and the circumstances of the eclipse are advanced by more than four *nāḍīs.* The opposite happens for the sunset people, and the circumstances are delayed by four *nāḍīs.* The duration itself is shortened by a slow rate of change of parallax for both. Therefore when the mid-day people's eclipse begins, the morning people's eclipse has ended, and when it ends, the evening people's eclipse has not begun. So there is no overlapping of them. The explanation given by me is general, and several other circumstances will have to be taken into account. But VM's statement is correct in a general way. Hindu astronomers give the maximum parallax converted into time as four *nāḍīs.*

We must contrast this with the lunar eclipse, which begins and ends at the same moments, wherever the Moon is visible on the earth.

7a. A.B. यद्यं (B. द्य) द्युदये; C. ग्रासे ह्युदये
b. A.B. निचस्थो A. ॰मंशुमा भवति
c. A.B. चन्द्रोपरमवस्थो; C. चन्द्रः परमोच्चस्थो;
D. चन्द्रो पर[स]मवस्थो
d. A1. धनद्धानोः; A2. द्यनद्धानोः;
B. घनह्य (B3. घ्रा) तो
In B2, there is transposition of folios here.

8a. B. Hapl. om of one ये
b. B. दिवनाथः
d. B. तेषां मेयिनमुग्रापत ग्रहणम् |
9a. B. तदानीतमु—यश्रंमानां
b. A.B. नेष्पदस्तदोषानाम् (B3. सेष्प)
c. A. देशे
d. B. मनपरत वर्तमान; B. gap for, न || उ
(of next verse)

(उक्तश्च) संहितायां मया प्रपञ्चोऽ(स्य) राहुचारादौ ।
ग्रहणस्य यन्निमित्तं विनै[व] राहुं रविहिमांश्वोः ॥ १० ॥

10. This matter of eclipses has been expatiated upon by me at the beginning of the chapter on Rāhu's (the Node's) motion (in the *Bṛhatsaṁhitā*, 5. 8-11). Also the causes for the eclipse of the Sun and the Moon without the consideration of Rāhu has been dilated upon.

VM indicates both the nodes as Rāhu (the dragon of mythology), one as the 'head' and the other as the 'tail'. Here, VM takes the correct astronomical position in the matter of the eclipses. In this chapter as also as in his *Bṛhajjātaka*, VM refers to without inhibition, the incorrect views of the authors of the early astronomical *saṁhitās*.

[ध्रुवस्य स्थानम्]

मेरोर्न दिग्विभागो यस्मात् प्राची न भास्करात्तस्मिन् ।
उदय(ते) याव(द्दि)वं पर्येतीव सुन्दरी तावत् ॥ ११ ॥
अणुमात्रदर्शनात् प्राग्विभाग इति चेत् समार्धमि(त्वा तु) ।
तस्मिन्नेवाऽस्तमये किं वा प्राची भवेत् त्वपरा ॥ १२ ॥
तेषामपक्रमवशाद्दिवसो न खलु भ्रमाद्यथास्माकम् ।
षष्टिर्नाड्योऽस्माकं वर्षमहोरात्रममराणाम् ॥ १३ ॥
वर्षे वर्षे द्युनिशं सुरासुराणां विपर्ययेणाह्नः ।
मासं तु तत् पितृणां मनुजानां नाडिकाषष्टिः ॥ १४ ॥
यन्मात्रं भूवृत्तात् क्षण[मात्रेणो]न्नतिं व्रजत्यर्कः ।
तन्मात्रान्तर(चा)रिणममराः पश्यन्ति नो(र्ध्व)म(तः) ॥ १५ ॥
होराधिपतिदिनेश्वरपरम्परा न [घ]टते यथास्माकम् ।
षष्टिर्नाड्यस्तस्मि[न्] नाहोरात्रो भवति यस्मात् ॥ १६ ॥

Situation at the Poles

11. There is no distinction of direction at the North pole, because East cannot be determined there using the Sun (rising and setting and culminating), for, as long as the Sun stays risen, it goes round and round the sky like a beautiful damsel.

The idea is that there is no daily rising and setting of the Sun to determine east and west. In fact, at the North pole all directions are south.

10a. A1.उक्तं च; A2.उक्तं व; B.—क्तं च
b. B.संतायामवाप्रपंचोस्य
c. A1.यन्निमितं; B.यनिमितं
d. A.B.विनैराहुं (B.हु)
B.हुपरपि हिमांश्च

11a. B1.2.दिविभागो
b. B.भास्करामस्मिन्
c. B.नदयति
d. A1.यावद्विवं; A2.यावर्दिवं;
B.यावद्विपर्येतीव
C.D.यावद्दिनपः पर्येति वसुन्धरीं तावत्

12. If it is argued that from the point where the Sun just appears above the horizon east is determined, as the Sun sets at the same point after half a year, can this east become west also?

What VM says in these two verses is essentially true. But his statement that it sets at the same point after half a year is not correct. It is not exactly half a year, and the Sun will disappear at any point proportionate to the fraction remaining over the full sidereal days gone between rising and setting.

13. For the gods at the North Pole, the day is determined by the Sun's declination, (north declination being day-time, and south declination night), not like ours, depending on the daily rotation. It is 60 *nāḍikās* for us, and one year for the gods.

14. Every year the day and the night of the gods and of the asuras (demons, at the South Pole) is opposite, (i.e. when it is day-time for the gods it is night-time for the asuras, and vice versa); for the pitṛs (on the Moon), the day-night is one synodic month; and for men, it is sixty *nāḍikās*.

15. To the extent the Sun rises above the horizontal by two muhūrtas, (i.e. 24° above the horizon) to that extent the gods at the pole see the Sun rising above the horizon, and not more than that.

The Sun spirals round and round after rising, with its altitude increasing with its north declination. As the maximum declination is 24° (according to Hindu astronomy, and fairly correct at VM's time), the altitude never exceeds 24°. After that is spirals down.

16. The series of the Lords of the Horās and Lords of the days do not fit there as it does for us, because the sixty-*nāḍikā*-day-night does not obtain there.

This statement fits not only the pole, but also all places in the arctic zone, when the Sun seen above the horizon exceeds 24 hours. The *horā* is one *hour's* time, and the Lords of the *horās* are successively Saturn, Jupiter, Mars, Sun, Venus, Mercury and Moon, and again Saturn etc. The lord of the first *horā* after sunrise is the lord of the day. It can be see that the lord of the 25th *horā* is the lord of the day next in the day series. So, if the day is more than 24 hours, the two series cannot fit.

12a. A.B. अनुमात्र
b. A.B. समार्धमिवा नु (A2. ०मिचा नु; B. ०मित्वात्तु)
c. B. तस्मिन्वास्तमये
d. B. प्राचि भवेत् परा

13a. A. तेषामपक्रंम; B. तेवाम (B1.2. om म)
पक्रमवशादिवसो (B2. द्दि)
c. B. षष्टिर्नोर्द्धोस्माकं
d. B3. gap after णाम्; (B1.2. no gap)

14a. B. वर्षे वर्षेन्दुनिशं
c. B. मास तु A.B. पितृणां
d. B. मनुज्ञानां B. नाडिकषष्टिः

15. Quoted by Utpala on *BS* 17.4-5.
15a. B1. भ्रमत्का; B2. भ्रमवत्ता;
B3. भ्रमवता for भूवृत्तात्
b. A.C.D.U. क्षणद्वयेनोन्नतिं;
B. क्षणवृयेणोन्नति व्र (B3. ०णदाये)
c. A.B. वारिण (B. om ण)
d. B. पश्यन्ति
A. नोर्धमधः; B. नोधंमधः
16a. A. नटते (A. नद्यते) यथास्माकं
a-b. C. परम्परा तत्र नो यथास्माकम् |
D. परम्परा न स्यात्तु यथास्माकत्
c. A. तस्मिनाहो; B. षष्ठिनाड्यस्तस्मिन्नहो

[वारज्ञानम्]

दिनवारप्रतिपत्तिर्न समा सर्वत्र कारणं कथितम् |
(नह्येऽपि) भवति यस्मात् विप्रवदन्तेऽत्र दैवज्ञाः || १७ ||
द्युगणाद्दिनवाराप्ति(र्द्यु)गणोऽपि हि देशकालसम्ब(न्धात्) |
ला(टा)चार्येणोक्तो यवनपुरे(ऽर्धा)स्तगे सूर्ये || १८ ||

Weekday

17. The determination of the weekday is not the same everywhere. As no reason is given in this matter too, even astrologers disagree among thereselves.

The commencement of the day is fixed arbitrarily, as a matter of convention, like midnight, sunrise, sunset, etc, following the custom of different peoples.

18. The weekday is obtained from the total days commencing from a stated point of time, of a particular day at a particular place. Ācārya Lāṭadeva has said that the day begins at the exact (mean) sunset at Yavanapura.

This convention is that of the *Romaka* and the *Pauliśa Siddhāntas*, mentioned by VM in PS I 8-10, Lāṭadeva is said to have redacted these two *siddhāntas*. Yavanapura is Alexandria in Egypt, as can be fixed from the longitude correction for Ujjain in *PS* III. 13. see also I. 8 and note on p. 10 above.

[दिनगणना]

रव्युदये लङ्कायां सिंहाचार्येण दिनगणोऽभिहितः |
यवनानां निशि दशभिर्मुहुर्तैश्च तद्गुरुणा || १९ ||

लङ्कार्धरात्रसमये दिनप्रवृत्तिं जगाद चार्यभटः |
भूयः स एव सूर्योदयात्प्रभृत्याह लङ्कायाम् ||२० ||

देशान्तरसंशुद्धिं कृत्वा चेन्न घटते तथा तस्मिन् |
कालस्याऽस्मिन् साम्यं (तै)रेवोक्तं यथाशास्त्रम् || २१ ||

17-20. Quoted by Makkibhaṭṭa on *Si. Śekhara*, 2.10.
17a. A. वारप्रतिपत्ति न ; B. वारप्रप्रति पति न
b. M. कारणे कथिता
c. A.B.C.D.M. नेहापि

18-29. Quoted by Utpala on *BS* 2, pp. 31-32
18a. B. द्युगणांदिन
B1.2. °प्तिद्विगुणोपि; (B3. °प्तिर्द्वि°)
b. A1. संवधा; A2. संबन्धा; B.D. M.U. सम्बन्धः
c. A.B1.2. लाजाचार्ये
d. A.B. पुरेवा (B. या) स्तगे; M. चास्तगे

मध्याह्नं भ(द्राश्वेऽ)स्तमयं कुरुषू[त्तरेषु] केतुमालानाम् |
कुरुतेऽर्धरात्रमुद्य(न् भा)रतवर्षे युगपदर्कः ||२२ ||

उदयो यो लङ्कायां सोऽस्तमयः सवितुरेव सिद्धपुरे |
मध्याह्नो यमकोट्यां रोमकविषयेऽर्धरात्रः सः || २३ ||

अधिमासकोनरात्रग्रहदिनतिथिदिवसमेषचन्द्रार्काः |
अयन(र्त्वा)र्क्षगतिनिशाः समं प्रवृत्ता युगस्यादौ || २४ ||

अन्यद् रोमकविषयाद् देशान्तरमन्यदेव यवनपुरात् |
लङ्कार्धरात्रसमयादन्यत् सूर्योदयाच्चैव || २५ ||

सूर्यस्यार्धास्तमयात् प्रतिदिवसं यदि दिनाधिपं ब्रूमः |
तत्राऽपि नाऽऽप्तवाक्यं न (वा) युक्तिः काचिदन्याऽस्ति || २६ ||

सन्ध्या क्वचित् क्वचिदहः क्वचिन्निशा [दिवसपतेः] क्वचित् क्वचित् |
स्वल्पे स्वल्पे स्था(ने) व्याकुलमेवं दिनपतित्वम् || २७ ||

Day-reckoning

19. Simhācārya has declared that reckoning day-total commences at a sunrise in Laṅkā. The preceptor of the Yavanas has said that the day commences for the Yavanas ten *muhūrtas*, or twenty *nāḍikās*, in the night, (i.e. after sunset).

Hindu siddhāntas suppose Laṅkā to be on the equator, at the junction of the Ujjain meridian. Siṃhācārya's view is that of many later siddhāntas. The preceptor of the Yavanas mentioned is probably the Yavanācārya of the *Yāvanajātaka,* the well-known astrological work. There is a section devoted to astronomy also in that work. If the people in Greece are meant by Yavanas here, Yavanācārya perhaps tries to fit a Greek astronomical work into serviceability in Ujjain, for 20 *nāḍīs* after sun-set in Greece is the moment of sun-rise at Ujjain, assuming a rough longitude correction 10 *nāḍīs.*

20. Āryabhaṭa has said that the day commences at mid-night at Laṅkā. He himself again has said, the day commences from sunrise at Laṅkā.

Āryabhata has written two works. One is the wellknown *Āryabhaṭīya.* He has written another work, not extant now. It is referred to by others as the Midnight School and commences the day at midnight. Bhāskara I has given its system in chap VII of his *Karmanibandha,* better known as *Mahābhāskarīya.* The system given in this is the same as that of the *Saurasiddhānta* of the *PS.* Brahmagupta professes to follow this in his *Khaṇḍakhāyaka.*

19c. B. यवनानांशिनिशिभिगतैर्मु° A.D.U. °दशभिर्गतैर्मु°; M. यवना निशीह दश°

20. Quoted by Nīlakaṇṭha in his *Jyotirmīmāṁsā,* p.8, as also on *ABh.* Kāla. 16.

20a. Jy, N. समयात्
b. B1.3. प्रवृत्तिज्ञ-गाद; B2. प्रवृत्तिःजगाद A. चार्यमट्टः; B1.3. चार्थभटः
c. M, N, U. चार्कोदयात्

21. If it is argued that the different times for commencing the day can be accounted for by correction for longitude, it does not agree with what they themselves have said in this matter, according to the *śāstras*, (which is as follows).

22. 'The sun rising in Bhārata-varṣa, makes at that very moment, mid-day in Bhadrāśva-varṣa, sun-set in Uttara-kuru-varṣa, and mid-night in the Ketumāla-varṣa.

23. What is sun-rise at Laṅkā, that same moment is sun-set at Siddhapura, noon at Yamakoṭi, and mid-night in the Romaka-pura.

In the above two verses the early siddhāntic conception of a world geography is given briefly. The equator is the Jambūdvīpa, with the North Pole at its centre. Laṅkā is the point where the Ujjain meridian cuts the equator. The point 90° east of Laṅkā is Yamakoṭi, also called Yavakoṭi. Here seems to be a vague concept of Java, called Yavadvīpa, whose exact distance was not realised. Ninety degrees west of Laṅkā is Romaka-pura, answering to Rome, whose exact position was not realised. The antipode point of Laṅka is called Siddhapura. A vague notion of the Mayan and Aztec civilisation brought in by early exporters sailing the seas might have given rise to the idea. The astronomical idea of sun-rise, moon etc. is correct according to the conception. The four *varṣas* mentioned, Bhārata, Bhadrāśva, Kuru, and Ketūmāla are supposed to be situated round the North Pole, at its south, east, beyond the pole and west, from our stand point, in Bhāratavarṣa. The Purāṇas give seven divisions of the Jambūdvīpa, and these are the principal four. The purāṇic concept is that of an earlier period of a flat earth, with the mountain Meru at the centre with Jambūdvīpa arranged all round, transmitted by tradition. The Siddhāntas tried to fit whatever is possible of the Purāṇic geography, into the conception of the spherical earth, refuting the rest outright or explaining them away.

24. At the beginning of the yuga, the intercalary months, the omitted days, the planetary days, the lunar days, the first point of Meṣa, the Moon, the Sun, half-years, ṛtus, and the sidereal days, begin together (and can be reckoned anew).

25. The longitude correction reckoned from the Romaka region is different from that from Yavanapura. Reckoning time from mid-night at Laṅkā is different from that from sun-rise.

21a-b. B. द्धिं त्तचत्र (B3. °न°)
c. B. °स्मात् साम्यं (B3. साम्यां)
d. A. नैरेवोक्तं
B1.2.3. gap indicated for यथाशास्त्रं and part of the next line up to कुरुषू

22a. A. भद्रेष्वस्त; C.D.U. भद्राश्वेष्वस्तमयं
b. A.C.D.U. om उत्तरेषु and read
कुरुषु केतुमालानाम्;
B. .... तरेषु कार्लेतुलानानाम्
c. A. °मुद्यद्धारत
d. B2. युगंपदर्कः

23a. A. Hap. om of one यो;
B. दनग्रो यो लङ्कायां
c. A.B1. यमकोद्यां U. यवकोट्यां मध्याह्नं
d. B. रोमवियेर्द्ध U. रात्रं च

24a. B. 'अ' lost. B. रात्रिग्रह
b. B. दिवसमयूष A. मेषं
c. A. अयन-र्क्ष; B. अयनत्वर्क्ष; D. अयनत्वृक्षगति
A1. युगस्पादौ

25b. B. विषयादेशा
d. A. दन्यसूर्यो; B. दन्यः सूर्यो

26. If we determine the Day-lord from the half-setting of the Sun every day, there is neither traditional authority nor reasoning to support this.

27. Even in quite adjacent places, in one place there is sun-rise or sun-set, and not in the other, day-time in one place and night in the other, and vice versa. Thus, there is confusion among people in the matter of the Lord of the day.

होरावार्ता(प्ये)वं यस्माद् होरा दिनाधिपस्याद्या |
तस्याऽपरिनि(ष्ठा)ने होराधिपतिः कथं भवति || २८ ||

अविचार्यैवं प्रायो दिनवा(रे) जनपदः प्रवृत्तोऽयम् |
स्फुटतिथिवि(च्छे)दसमं युक्तमिदं प्राहुराचार्याः || २९ ||

28. The matter of determining the Horā-lord also is in the same mess. When the Day-lord is not determined, how can the Horā-lord be determined?

29. Without giving a thought to all these difficulties, people generally use the name of the Day-lord in their daily routine, (and get on with their work). Learned authorities say that the best thing would be to use the true *tithi,* (lunar day) and its parts for daily intercourse (as for fixing a definite point of time etc.)

What is meant is as follows:- Sun-rise etc. may vary from place to place, according to the local time. But the lunar day is the same for every place on the earth. So this can fix a point of time without any ambiguity. We learn that the ancient Babylonians used the lunar day as the unit of time, just as we use the solar day.

In the above verses VM indulges in a lot of discussion about Horā-lord, Day-lord, etc. But these are only matters of convention, and astrologers and governments can agree upon some convention to avoid difficulties, e.g. do we not have the standard mean time for our daily dealings.

26a. B.०र्धस्तमयात्
b. B.०दिवस यदि B.दिनाधिपत्यं A2.ब्रूमः
c. B.नाप्तं वाक्यं
d. A.नवयुक्तिः; B.C.D.न च युक्तिः
B.०दन्यास्तः; U.०दप्यस्ति

27b. A.B.निशा दिनपतिः
A2.क्वचिक्वचित्
c. A.B.स्थानं
d. D.व्याकुलमेव

28a. A.वार्त्तथेवं; B.वत्ताप्येवं (B3.०र्त्ता०)
b. B.०धिपश्चाद्याः
c. A.निष्ठाने; B.निष्टाने

29a. U.अविदित्वैवं
b. A.वारौ; B1.2.वारै; B3.वारैः
c. B.स्फुरतिथि A.B1.3.विछेद
d. B1.राचार्योः

[इति पञ्चसिद्धान्तिकायां वराहमिहिरविरचितायां ज्यौतिषोपनिषन्नाम पञ्चदशोऽध्यायः ||] [1]

Thus ends Chapter Fifteen on 'Secrets of Astronomy' in the Pañcasiddhāntikā composed by Varāhamihira

1. Col.: A.B.D.ज्यो (A1.ज्यौ) तिषोपनिषत् पञ्चदशो
(B.दशमो) ध्यायः |
C.इति ज्योतिषोपनिषन्नाम पञ्चदशोऽध्यायः ||

Chapter Sixteen

SAURA SIDDHĀNTA : MEAN PLANETS

१६. षोडशोऽध्यायः
सौरसिद्धान्तः — ग्रहमध्यमानयनम्

Introductory

Chapter XVI of the *Pañcasiddhāntikā* deals with the computation of the mean star-planets, Mars etc., according to the *Saura Siddhānta,* and chapter XVII of their true motions, with their heliacal risings and latitudes. The mean planets are made true by employing the method of epicycles, as in the case of the Sun and the Moon, in chapters XI and X. Of the five *siddhāntas* condensed by Varāhamihira the *Saura* alone uses epicycles, and there is no evidence of its use in any other. So, in the originals also, only the *Saura* must have used epicycles, since VM follows the originals as far as necessary. Thus the *Saura* is the most mature, and may be considered to begin the highest developed stage of Hindu astronomy, represented by the *Āryabhaṭīya,* the *Brāhma-sphuṭa-siddhānta,* the *Later Sūrya Siddhānta* etc.

Though VM's *Saura,* being a *karaṇa,* does not use *yuga*-cycles for the planets, the original must have had them and they can be reconstructed from the epoch-constants given, as we have done in the case of the Sun, Moon, Moon's apogee and nodes. These can be seen to agree with the corresponding parameters of the *Pauliśa* quoted by Bhaṭṭotpala in his commentary on the *Bṛhatsaṁhitā,* and with the *Ārdharātrika-pakṣa* of Āryabhaṭa, a work now lost, but reconstructible from its description given in the *Mahābhāskarīya,* chapt.VII, 21-35, and from the *Khaṇḍakhādyaka* of Brahmagupta, which latter expressly follows the *Ārdharātrika-pakṣa.* Not only the *yuga*-cycles, but also the *yuga* days, and epicycles and apogee positions and nodes agree in these. Strangely enough, the *'New' Sūrya Siddhānta* does not agree with the *'Old'* in many things. In the matter of computing the latitudes of the star-planets, the *Saura* gives the same method as the *Ārdharātrika-pakṣa* combining two types of latitudes, but the *Khaṇḍakhādyaka* follows the *Āryabhaṭīya* itself exactly as propounded *in the Mahābhāskarīya,* VI. 52-55.

As for agreement of VM's *Saura* with the other *siddhāntas* of the period, a perusal of the table given under XVII.11 will show this. But it must be noted that the agreement in mere number of cycles is not real agreement, because, the *yuga* days being different, there will be difference in the calculated mean values. But at the period we are considering, viz. *c.*500 A.D., the mean positions fairly agree with one another, and also with what would be got by modern astronomy, showing thereby the accuracy of their observations. For example, for *PS's* epoch, all except the *later Sūrya Siddhānta* give nearly 236° for Rāhu, including the moderns. This is seen only in the Rāhu of the *Later Sūrya Siddhānta.* (Evidently, there is error of reading here. In I.33 of the *Later Sur. Sid.*, the original should have been *vasvaśviyamāśviśikhidasrakāḥ* instead of *vasvagni* etc. This mis-reading must have occurred before the commentator Raṅganātha, for he gives *aṣṭarāmākṛtirāmadvimitāh.* If what I suggest is correct, 3° will be added to the 232° 29′ got according to the wrong reading making Rāhu = 235° 29′, giving fair agreement). There is agreement in the degrees for heliacal rising and setting and the method of computing the star-planets between the *Saura* of the *PS* and the *Later Sūrya Siddhānta,* though the epicycles differ in many ways.

Another important matter should be mentioned. In XVI. 10-11, and XVII. 10-11a, VM gives corrections, which are his own, to secure agreement with observation to make the *Saura* fit for correct almanac-making, which naturally will be demanded by the literate. Thus, in XVI.10-11, certain *bījas* are given to correct the means of Mars, Jupiter and Saturn and the *śīghra* of Mercury and Venus. The corrections amount, in terms of *yuga*-cycles, to: Mars, + 57; Mercury, + 400; Jupiter, − 33½; Venus, − 150; and Saturn, + 25. These corrections are similar and approximately equal to the famous *Vāgbhāvona* correction on the *Āryabhaṭīya*, propounded by his successors in his school, to correct his cycles to agree with their observation. I do not suggest that VM was aware of the *Vāgbhāva* correction in that form, but the tendency to correct the earlier results with *bījas* based on observations is found everywhere, whether north or south, a healthy sign of the growth of the science. One might refer also to XVII.10-11a, where VM attempts to correct Mercury and Venus to secure agreement with observation.

Another thing is to be noted. In (1) the *Āryabhaṭīya*, in (2) the *Ārdharātrika-pakṣa* (which means ipso facto the *Khaṇḍakhādyaka*), VM's *Saura* and Bhaṭṭotpala-quoted *Pauliśa*, and in (3) the *Later Sūryasiddhānta*, the *yuga* cycles are such that the mean planets are all zero at the beginning of Kali, the Moon's apogee is 90°, and the Moon's node 180°. Now the *Āryabhaṭīya* had equal *yuga-pādas, Kṛta, Tretā, Dvāpara* and *Kali,* i.e., they are equal in length. The other *siddhāntas* have unequal *yuga* divisions, *Kṛta* being 4 parts, *Tretā* 3 parts, *Dvāpara* 2 parts and *Kali* 1 part. If the other *siddhāntas* also postulate, like the *Āryabhaṭīya,* that the planets were created and began to move from the beginning of the *Kalpa* from a zero position, then the cycles should be divisible by 20. But they are not so divisible in all. This necessity is avoided by postulating a time later than the beginning of the *Kalpa* called 'the time of creation of planets' by the *Later Sūrya-Siddhānta*, as started in the verse,

graharkṣadevadaityādi sṛjato'sya carācaram
kṛtābdhivedā divyābdāḥ śataghnā vedhaso gatāḥ || *I.24* ||

and by having both the number of cycles and *yuga*-cycles divisible by four. In the case of the Moon's apogee, the cycles should be odd, and in the case of Rāhu the cycles should be even, but not divisible by 4. These necessary conditions are indeed found in the *Later Sūrya Siddhānta* and its kind. Thus, if there is any observed difference in the mean planets, Moon's apogee and nodes, they must be due to the 3600 years elapsed after Kali, for the period *c.*499 A.D. But the observed differences should be only small, and due to error of observation. The cycles must have been, and have been, constructed with an eye to this also. In fact, the number of cycles have been determined by observation, and by using the Diophantine equation (*kuṭṭaka*). The difference of just 300 days in the length of the *yuga,* (it does not matter much if it is 328 days, as in the *Later Sūrya Siddhānta*) to secure equality at *c.*499 A.D., between the *Ārdharātrika-pakṣa* and the *Āryabhaṭīya*, which is called, for the sake of distinction, the *Audayika-pakṣa,* meaning the type beginning the day from mean sunrise at Ujjain, provided the number of cycles are the same. (See tables under XVII.11). There is a difference of just a quarter of a day accumulated from zero Kali to *c.*499 A.D. and the difference is made zero at this point of time.

[ताराग्रहाणां मध्यमानयनम्]

एष निशार्धेऽवन्त्यां ताराग्रहनि(र्णयोऽ)र्कसिद्धान्ते |
तत्रेन्दुपुत्रशुक्रौ तुल्यगतौ म(ध्य)मार्केण || १ ||

Mean positions of the star-planets

1. The following is the determined position of the star-planets at midnight at Ujjain according to the *Saura Siddhānta*. For their computation, the mean Sun should be taken as the mean Mercury and Venus.

Note: I follow TS's emendations.

Example: Find the mean Venus at 1,20,553 days after Epoch for the star-planets, viz. 427 śaka elapsed midnight at Ujjain.

This is the mean Sun at 1,20,553.5 days from midday of the Saura epoch, (vide expl. under IX. 1). Therefore the mean Venus = the mean Sun = 1,20,553.5 × 800 − 442) ÷ 2,92,207 = 17° 18′ 27″.

जीवस्य 'शता'भ्यस्तं 'द्वित्रियमाग्नित्रिसागरै' (र्वि) भजेत् |
द्युगणं कुजस्य चन्द्राऽऽहतं तु 'सप्ताष्टषड्' भक्तम् || २ ||
सौरस्य 'सहस्र'गुणा(द्) 'ऋतुरस(शू)न्यर्तुषट्कमुनिखैकैः' ||
यल्लब्धं ते भगणाः शेषा म(ध्य)ग्रहाः क्रमेणैव || ३ ||
दश दश भगणे भगणे संशोध्यास्तत्पराः सुरेज्यस्य |
'मनवः' कुजस्य देयाः शनेश्च 'बाणा' विशोध्या(स्तु) || ४ ||
राशिचतुष्टयमंशद्वयं कलाविंशतिर्वसु'समेताः |
'नववेदा'श्च विलिप्ताः शनेर्ध(नं) मध्य(मस्यै)व || ५ ||
अष्टौ भा(गा) लि(प्ता)'(ऋत)वः' 'ख(पक्षौ)' गुरौ विलिप्ताश्च |
क्षेपः कुजस्य '(य)मतिथि-पञ्चत्रिंश'च्च राश्याद्याः || ६ ||
शतगुणिते बुधशीघ्रं 'स्वरनवसप्ताष्ट'भाजिते क्रमशः |
अत्रार्धपञ्चमास्तत्पराश्च भगणाह(ताः) क्षेपः || ७ ||
सितशीघ्रं दशगुणिते द्युगुणे भक्ते 'स्वरार्णवाश्वियमैः' |
अर्धैकादश देया विलिप्तिका भगणसंगुणिताः || ८ ||
सिंहस्य 'वसुयमां'शाः 'स्व(रेन्द)वो' लिप्तिका ज्ञशीघ्रधनम् |
शो[ध्याः] सितस्य विकलाः 'शशिरसनवप[क्ष]गुणदहनाः' || ९ ||

[वराहमिहिरकृतः शोधः]

क्षेप्याः 'स्वरेन्दु'विकलाः प्रतिव(र्षं) मध्यमक्षिति(जे) |
दश दश गुरोर्विशोध्याः शनैश्चरे सार्धसप्तयुताः || १० ||
'पञ्चा(ब्ध)यो' विशोध्याः सिते बुधे 'खाश्विचन्द्र'युताः |
'खखवेदेन्दु' विकलिकाः शोध्याः [स्युः] सुरपूजितस्य मध्याः स्युः || ११ ||

2-9 *To get mean Jupiter,* multiply the days from epoch by 100, and divide by 4,33,232. Revolutions etc. are got. Deduct 10‴ per revolution. Add 8° 6′ 20″, the mean at epoch (This is called *kṣepa.*) (A *bīja* correction is given by VM, to this, for which see verses 10-11, below.)

To get Mean Mars, divide the days by 687. Revolutions etc. are got. Add 14‴ per revolution. Add 2^r 15° 35′ 0″, the mean at epoch. (See verses 10-11, below, for *bīja* correction.)

To get mean Saturn, multiply the days by 1000 and divide by 1,07,66,066. Revolutions etc. are got. Deduct 5‴ per revolution. Add 4^r 2° 28′ 49″, the mean at epoch. (See verses 10-11, below, for *bīja* correction).

To get the Śīghra of Mercury, multiply the days by 100 and divide by 8797. Revolutions etc. are got. Add 4½‴ per revolution. Add 4^r 28° 17′ 0″, the *Śīghra* at epoch. (See verses 10-11, below, for *bīja* correction.)

To get the Śīghra of Venus, multiply the days by 10 and divide by 2247. Revolutions etc. are got. Add 10½″ per revolution. Add 8^r 27° 30′ 39″, the *śīghra* at epoch. (See verses, 10-11, below, for *bīja* correction).

1a A.॰र्घेवत्पां; B. धैवत्यां
b. A.निर्णोर्कसिधांते; B. गहणकसिद्धान्ते
c. A.महमार्केण; B. मध्यमार्कसा
2a. B.जिवस्य B2.शताभ्यासं
b. A1.C.॰यमाग्निचिसागरैर्विभजेत्;
B.॰विभजेन
d. A1.हतं A1.॰ष्टब्द्रक्तं
3a. B. repeats words from previous verse:
सौम्यस्य सत्ताभ्यस्तं द्विन्नियमाग्निसागरैः सहस्त्रगुणा
a-b. D.गुणमृतु
b. A.दतुरससून्यर्त्तु; B.रुतु॰ B.खैकः
d. B1.2.D.शेषा मध्या
4a. B1.3.दशांश भगणे and one भगणे
om by haplography
b. B.॰ध्यास्तसराः
c. B.नमवः कुकुक्षु देया
d. B1.3.शनैश्च B3.विशोध्य A.॰स्तु; B.स्युः
5a. B.॰मंशं
b. B3.॰शतिवसु C.D.समेता
c. B.॰वेदाश्वलिप्ताः
d. A.॰धनेर्मध्यमास्येव; B.शने मध्यमस्त्वेयम्
6a. A.भामा लिप्त; B.मागाः लिप्त
b. A.C.D.र्त्तवः; B.तवः;
A. खमक्षोगुरौ (A2. ॰क्षौ॰); B. तवः शेषसौ गुरु वि;
C.खमक्षो गुरौ; D.खपक्षो गुरोः
c. B.क्षेवः A.जमतिथि; B.यमतितिथि
d. B.त्रिशद्य
7a. B.गुणितं
c. B. ॰र्धपंचमौस्त॰ (B3. ॰स्तस.
d. A.हतः; B.हतक्षिपा; C.D.क्षेप्याः
8a. B.गुणीते
b. A.॰वाश्वियमैः
c. A1.अक्कैका॰; A2.अर्कैका
d. A.विलिप्ता
9a. A.सिंहस्प; B.सिंहेस्य
b. A.खरेन्वो; B.स्वरे देवो विलिप्तिका
c. A.शोसितस्य; B3.शोषितस्य B.विकला
d. A.B.पक्षा गुणा दहनाः (A.ताः)
10a. A.B.क्षेप्या B.विकला
b. A.B.वर्षमाध्यम A.B.क्षितिजो
11a. A.B1.2 पञ्चद्वयो; B3. ॰द्वयोः
b. A.B.॰स्ताश्वि B.चन्द्रयुक्ताः
c. A.B.विकालिकाः
d. A.B.C.D. om स्युः B.सुर —— प्तजितस्य
(B3.पू). A.B.C.D.मध्यात्
In D.ch. XVII of the Mss. and of C is continued as part of ch.XVII. with verse numbers duly altered.

Note 1. I follow TS's emendations, except in verse 6, where I have read *khamakṣau* as *khapakṣau* instead of their *khamakṣo*, *makṣo* being meaningless. But their meaning, 20, is all right. In 7, the word *kṣepa* can stand, and need not be emended as done by them.

Note 2. The word *madhya* with reference to Mars, Jupiter and Saturn is mean planet in modern parlance, and *śīghra* with reference to Mercury and Venus, is mean planet according to modern terminology.

Note 3. How to get the days from epoch has already been explained, and it should only to be brought to the mid-night following to be used here.

Example 1. Find the mean Mars at 1,20,553 days from the midnight following the Romaka epoch, which is the epoch given for star-planets.

1,20,553 ÷ 687 = 175 revolutions and	=	5^r	21°	52′	40″
The revolution correction = 175 × 14‴	=				+ 41″
Kṣepa or mean at epoch	=	2^r	15°	35′	0″
Mean Mars at required date	=	8^r	7°	28′	21″

Example 2. Find the Śīghra Venus at 1,20,553 days for epoch.

1,20,553 × 10 ÷ 2247 = 536 revolutions and		6^r	2°	19′	23″
Revolution Correction: 536 × 10½″	=		+ 1°	33′	48″
Śīghra at epoch	=	8^r	27°	30′	39″
Śīghra of Venus at 1,20,553 days	=	3^r	1°	23′	50″

Note 4. The rules give to find the mean planets etc. depend on the fact that there are approximately 100 revolutions of Jupiter in 4,33,232 days, one revolution of Mars in 687 days, 1000 revolutions of Saturn in 1,07,66,066 days, 100 *śīghra* (truly mean) revolutions of Mercury in 8,797 days and 10 of Venus in 2247 days. The revolution corrections make these exact. The epoch constants are the means at epoch.

Note 5. From the rules given we can reconstruct the *yuga* cycles of the original *Saura-siddhānta* of which the *Saura* of the *PS* is a *Karaṇa,* and from these the epoch constants. These we shall do now. The *yuga* days of the original *Saura* are 1,57,79,17,800, as computed from the short *Saura yuga* given in I.14, from which it can be computed that in 1,80,000 years there are 6,57,46,575 days, since the *yuga* is 43,20,000 years, being 24 times the short *yuga.*

We might now verify by calculation, the *yuga* revolutions (*yuga-paryaya*) and epoch constants (*kṣepa*) of the several planets.

Jupiter: Yuga revolutions

1,57,79,17,800 × 100 ÷ 4,33,232 = 3,64,220, rev.		0^r	17°	25′	1″
Revolution correction = 3,64,220 × 10‴	=		− 16°	51′	43″
∴ The number of rev. etc. in the *yuga* = 3,64,220 rev.,		0^r	0°	31′	18″

The error in the *karaṇā* method is 31′ 18″ in 43,20,000 years, which is negligible when we consider that the rule is given in a *karaṇa*, which is not intended to be used for such a long period. The *yuga* revolutions 3,64,220, is indeed that given in the original, as seen from the *Ārdharātrika-pakṣa* and Bhaṭṭotpala's *Pauliśa* and *Khaṇḍakhādyaka*.

Epoch Constant (kṣepa) for Jupiter

The epoch is 427 Śaka i.e. 427 + 3179 = 3606 years from zero Kali, i.e. midnight, − 3 *nāḍis*, 9 *vināḍis*. For 3606 years, the motion is $3,64,220 \times \left(\frac{1}{1200} + \frac{1}{1200 \times 600}\right) =$

	304 rev.,	0ʳ	8°	6′	36″
Subtracting the motion for 3 *nāḍis*, 9 *vināḍis*,					− 16″
Jupiter's epoch constant got	=	0ʳ	8°	6′	20″

This is exactly what is given above in verse 6.

Saturn: Yuga revolutions

1,57,79,17,800 × 1000 ÷ 1,07,66,066 =	1,46,564 rev.,	0ʳ	3°	26′	12″
The cycle correction = 1,46,564 × 5‴	=		− 3°	23′	34″
∴ The *Yuga* cycles got =	1,46,564 rev.,	0ʳ	0°	2′	38″

This is indeed the *yuga* cycles given in the *Ārdharātrika-pakṣa* etc. neglecting the small error of 2′ 38″ accumulating in 43,20,000 years, due to the *karaṇa* roughness.

Epoch constant for Saturn

$1,46,564 \left(\frac{1}{1200} + \frac{1}{600 \times 1200}\right) =$	122 rev.,	4ʳ	2°	28′	5″
Deducting for 3 *nāḍis*, 9 *vināḍis*					− 6″
The epoch constant got =		4ʳ	2°	28′	49″

Mars: Yuga revolutions

1,57,79,17,800 ÷ 687 =	22,96,823 rev.	6ʳ	29°	4′	59″
Rev. Correction = 22,96,823 × 14′″ =		+4ʳ	28°	52′	5″
∴ Yuga-cycles =	22,96,823 rev.	11ʳ	27°	57′	4″

= 22,96,824, in round numbers, being short only by 2° 3′, negligible in the long period. We see agreement with the original.

Epoch constant for Mars

The epoch constant is

$$22,96,824 \left(\frac{1}{1200} + \frac{1}{600 \times 1200}\right) = 1917 \text{ rev.,} \quad 2^r \ 15° \ 36′ \ 43″.2$$

Deduction for 3 *nāḍis*, 9 *vināḍis*		− 1′ 39.5″
Less 1917‴ ÷ 5		− 6″
The epoch constant	=	2ʳ 15° 34′ 58″

There is agreement.

Mercury: Yuga revolutions

1,57,79,17,800 × 100 ÷ 8997 =	1,79,36,998 rev.	11ʳ	21°	41′	33″
Rev. Correction = 1,79,36,99 × 4½‴	=	+1ʳ	13°	41′	15″
The *Yuga* cycles = 1,79,37,000 Rev.		0ʳ	5°	22′	48″

There is fair agreement with the *Ārdharātrika-pakṣa* etc. with an excess of 5° 22′ 48″ in the *yuga*, which need not be considered great in a *karaṇa* rule. 4 7/16 instead of 4½‴ would have taken this difference also into account.

Epoch constant for Mercury

$1,79,37,000 \left(\frac{1}{1200} + \frac{1}{600 \times 1200}\right) =$		14,972 rev.,	4ʳ	28°	30′	0″
Subtracting for the excess 3 *nāḍis*, 9 *vināḍis*					− 23′	53″
For 1/16 repeat the correction						+ 16″
Epoch constant	=		4ʳ	28°	17′	23″

Here the constant seems to have been given to nearest minute.

Venus: Yuga revolutions

1,57,79,17,800 × 10 ÷ 2247	70,22,331 rev.	1ʳ	8°	55°	54″
Revolution correction = 70,22,331 × 10½ =	56 Rev.	10ʳ	21°	47′	52″
Yuga cycles = 70,22,388		0ʳ	0°	43′	46″

There is a small error of 43′ 46″, negligible in the long period of *yuga*, owing to the *karaṇa* rule. 10 85/178 would have been very correct.

Epoch constant for Venus

Epoch constant, $70,22,388 \left(\frac{1}{1200} + \frac{1}{600 \times 1200}\right)$ = 5861 rev.		8ʳ	27°	35′	38″.4
Less for 3 *nāḍis*, 9 *vināḍis*		−		5′	2″
Extra in the correction		+		2′	4″
Epoch correction (in full agreement)	=	8ʳ	27°	30′	39″

In the Sun, Moon, Rāhu, and Moon's apogee too we see much exact agreement with *Ārdharātrika-pakṣa*, *Khaṇḍakhādyaka* and *Bhaṭṭotpala*-quoted *Pauliśa*, from which we can conclude that the source of VM's *Saura* is the *Old Saura-siddhānta*.

VM's Bīja corrections

10-11. Add 17″ per year to mean Mars. Deduct 10″ per year from mean Jupiter. Add 7½″ per year to mean Saturn. Add 120″ per year to the *śīghra* ('mean' according to modern parlance) of Mercury. Subtract 45″ per year from the *śīghra* (modern 'mean') Venus. In addition, subtract 1400″ or 23′ 20″, constant from Jupiter's mean.

Note.1 I follow TS's corrections.

Note 2. These corrections are obviously VM's own, to secure agreement with observation, because VM sees the *Saura* used widely for almanac making, (besides himself being its follower) and uses these *bīja* corrections to the *Saura*. Being VM's own, we cannot verify the numbers used, but we can compare these corrections with those given by the followers of the *Āryabhaṭīya* belonging nearly to his time. Note how close they are, and commend the tendency to observe and correct, instead of blindly following the masters.

The Kerala school following the *Āryabhaṭīya* gives the well-known *vāgbhāva* correction:

vāgbhāvonāc chakābdād dhanaśatalayahān mandavailakṣyarāgaiḥ
prāptābhir liptikābhir virahitatanavaś candratattuṅgapātāḥ |
śobhānīrūḍhasaṃvidgaṇakanarahatān māgarāptāḥ kujādyāḥ
saṃyukytā jñārasaurāḥ suragurubhṛgujau vajitau bhānuvarjam ||

(*Kaṭapayādi* notation is used here.) According to this the corrections per annum are for Mars + 11.5″, for Mercury + 105″, for Jupiter − 12″, for Venus − 39″, and for Saturn + 5″. See that these compare well with VM's.

Example: Give the bīja corrections for Mars and Venus at 1,20,553 days from epoch.

This is 330 years. The correction for Mars = 330 × 17″ (positive) = + 1° 33′ 30″.

The correction for Venus = 330 × 45 (negative) = − 4° 7′ 30″.

Thus *bīja*-corrected mean Mars of date is 8ʳ 9° 1′ 51″, and *bīja*-corrected Venus, 2ʳ 27° 16′ 20″.

[इति पञ्चसिद्धान्तिकायां वराहमिहिरविरचितायां
सौरसिद्धान्ते मध्यमानयनं नाम षोडशोऽध्यायः ||]

Thus ends Chapter Sixteen entitled 'Saura-Siddhānta – Mean Planets' in the Pañcasiddhāntikā composed by Varāhamihira

1. Col.: A.B.D. सूर्यसिद्धान्ते मध्यगतिः (B. शनि for गति)
(D. gives this as a section colophon).
C. इति सूर्यसिद्धान्ते मध्यगतिर्नाम षोडशोध्यायः

Chapter Seventeen

SAURA-SIDDHĀNTA — TRUE PLANETS

१७. सप्तदशोऽध्यायः
सौरसिद्धान्तः — ताराग्रहाणां स्फुटीकरणम्

As stated earlier, the computation of the Saura star-planets is continued in ch. XVII, the topics treated being, the True planets, their heliacal risings and their latitudes.

[स्फुटकर्म]

शीघ्राख्योऽ र्कोऽन्येषां भौमादीनां तु परिधयो द्विगुणाः ।
'पक्षस्वरा' (श्च खं षड्यमाः)' 'खकृता' श्चकुजादीनाम् ॥ ३ ॥

Epicycles of the planets

1. For the other planets (i.e. other than Mercury and Venus, *viz.*, for Mars, Jupiter and Saturn), the Sun is their *Śīghra*. The epicycles of equation of the apsis of Mars etc. are twice, 35°, 14°, 16°, 7°, and 30°, (i.e., of Mars 70°, of Mercury 28°, of Jupiter 32°, of Venus 14° and of Saturn 60°.)

Note 1. I follow TS's emendation in *pañcatriṁśanmanavaḥ*. But I read *surāḥ* as *svarāḥ* and not *śarāḥ*, like TS because *svarāḥ* is nearer the given reading *surāḥ*, and also 14° is the epicycle given in the *Ārdharātrika-pakṣa* etc. Five *mātrās* are wanting in the last foot, and it must be supplied with some such words as *bhāgāḥ*, as all numbers are already given. But TS make it *ṣaḍyutās-triṃśāḥ* and, strangely enough, translate it as 24, confusing the addition mentioned by themselves for subtraction. (However, on page XXIII of the Introduction Thibaut gives the correct 30° × 2 = 60°.)

Note 2. The first foot is to be read with verses 7 and 8 of chap. XVI where the *śīghra* of Mercury and Venus have already been given. Properly speaking, the matter in the foot should have been given in chap. XVI.

'रस-भव-वसु-वेदा-र्का' विंशतिगुणिताः कुजस्य दशको(ना): ।
मन्दगति नाम (?) भागाः कुजबुधगुरुशुक्र(सौ)राणाम् ॥ २ ॥

2. 6, 11, 8, 4, 12 multiplied by 20, Mars's being less by 10°, (i.e. 110°, 220°, 160°, 80°, and 240°) are the apogee positions of Mars, Mercury, Jupiter, Venus and Saturn.

1a.˘ B.र्को
b. ०नां नु परिं; D.तु [मन्द] परिधयः [स्युः] ।
c. D.द्विगुणाःपञ्च० A.त्रिशत्सनवो
d. A.सुरास्त्रिंशाः ॥ B.०ष्टंयः सुरास्त्रिंशा ॥; C.०ष्टयः शराः षड्युतास्त्रिंशाः ॥;
D.०ष्टयः स्वस्त्रिंशा [श्च] ॥

Note 1. I follow TS's emendations. *Mandagatināmabhāgāḥ* does not make any sense. But the meaning is obvious, it must mean apogee positions. Some drastic emendation of the word can be made to give this meaning, but I am against such as emendation.

Note 2. These positions agree with those given in the *Ārdharātrika-pakṣa* etc., as also in the *Āryabhaṭīya*. The correct positions according to modern astronomy are 128°, 234°, 170°, 290°, and 244°, respectively.

Note 3. The apogee 80° for Venus and the epicycle 14° are the same as given for Sun. The apogee position 80° given is near the perigee position of modern astronomy, so far away. We shall explain this under verses 10-11a, below.

शीघ्रपरिधावथांशाः 'कृतगुणप(क्ष)'-द्विवह्निशीतकराः' |
'पक्षस्वरा'(श्च खंषड्य माः)' 'खकृता' श्वकुजादीनाम् ||.३ ||

3. The degrees of epicycles of conjunction of Mars is 234, of Mercury 132, of Jupiter 72, of Venus 260, and of Saturn 40.

Note 1. I have generally adopted TS's corrections. But the text is corrupt in the third foot, and TS's correction itself wants one *mātrā*. I would read the third and fourth feet thus:

pakṣasvarāś ca kham ṣaḍyamāḥ khakṛtāś ca kujādīnām.

This would follow the original work.

Note 2. The values agree with the *Ārdharātrika-pakṣa, Khaṇḍakhādyaka,* and *Bhaṭṭotpala*-quoted-*Pauliśa* group, as to be expected.

[स्फुटग्रहाः]

शीघ्रान्मध्यमहीनाद् (रा)शित्रितये गतैष्यदं(श)ज्ये |
भुजकोटी तत्परतः षड्(भिः) प(ति)ते स एव विधिः || ४ ||
स्वपरिधिगुणिते भाज्ये 'खर्तुगुणै' [स्ते] विप(रिण)ते तच्च |
कोटिफलं व्यासार्धे मृगकर्क्यादौ चयापच(यम्) || ५ ||
तद्भुज [कृति] योगपदैर्भा(ज्यं भुजजं 'ख)सूर्य'घ्नम् |
तच्चापार्धं मन्दे हानिधनं शीघ्रकेन्द्रवशात् || ६ ||

2a. B. रससंवत्सुवेदार्को (B2. रसंस०)
b. B. गुणिता A. क्रजस्य A. दशकोणाः; B. दशकोणस्पणाः (B2. ०स्पणाः; B2. स्यदणाः)
c. D. गतीनां भागाः B. नाम लाधवं || कुज
d. A. शुक्रसोराणां०

3a. B. परिधा यथाशा
b. B. तत्तदगुण० A.B.C.D. पक्षा द्वि. B1.2. वाह्नि
c. B. om पक्षस्वराः A. स्वराऽऽऽऽ खंवद्य B. खषद्य
d. A.B. मा ख (B3. माःख) C.D. कृताःस्युःकुजादीनाम्

True planets

The first step

4. Deduct the mean from the *śīghra*. If the remainder (called *śīghra-kendra)* is within 90°, sin. *śīghra-kendra* is called *bhuja*, and sin (90° – *śīghra-kendra*) is called *koṭi.*

If *śīghra-kendra* is more than 90° and less than 180°, subtract it from 180°. (Taking this as the *śīghra-kendra*, sin. *śīghra-kendra* is *bhuja* and sin (180° – *śīghra-kendra)* is *koṭi*. If *śīghra-kendra* is more than 180° and less than 270°, deduct 180° from it and take this as *śīghra-kendra*. Sin. *śīghra-kendra* is *bhuja* and sin (90° – *śīghra-kendra)* is *koṭi.* If śīghra-kendra is from 270° to 360°, deduct it from 360° and take its sine as the *bhuja* and sin 90° – *śīghra-kendra* is the *koṭi.* (The *bhuja* of *manda-kendra* is to be found in the same way using *manda-kendra* in the place of *śīghra-kendra)*[1]

5-6. The *bhuja* and *koṭi* must be multiplied by the planet's epicycle of conjunction and divided by 360. Thus transformed, they are called *bhuja-result* and *koṭi-result* pertaining to the equation of conjunction. If the *śīghra-madhya* is from 270° to 90°, the *koṭi-result* is to be added to 120 (the R. of the *PS*). If *śīghra-madhya* is from 90° to 270°, the *koṭi-result* is to be subtracted from 120. Square this and add it to the square of the *bhuja-result.* Find its square root, and by this divide 120 × *bhuja-result*. Find arc-sine of this. Subtract half this from the longitude of apsis if the *śīghra-kendra* is from 0° to 180°. Add if from 180° to 360°.

स्फुटयित्वैवं मन्दं मध्याच्च विशोध्य तस्य भुजम् |
परिणाम्य कार्मुकार्धं तन्मन्देनैव धनहानी || ७ ||

Second step

7. Half rectifying the apogee position thus, deduct it from the mean. The result is to be used as the anomaly of the apsis in the second step. As we find the *bhuja* of the anomaly of conjunction (*śīghra-kendra)* so find the *bhuja* of the anomaly of apsis. Multiply the *bhuja* by the *manda* epicycle and divide by 360. and get the transformed *bhuja-result* of the apsis. (This is sine equation of the

4.5. Quoted by Utpala on *BS*, 2. pp. 44-45

4a. U. मध्यविहीनाद्

b. A. वाशित्रितये A.B. गतैष्प (B2.3. ष्य)
A.B. ०दंशे ज्ये; U. ०दंशज्या

c. -B. कोटि

d. A1. षड्भ्याः; B.C.D.U. षड्भ्यः A.B. पतते

5b. A. गुणैर्विपगते तच्च; B. गुणे वियुगतश्च;
C.D. गुणैर्विप [रि] णते तच्च (D. णते ते ततश्च)

d. B. कर्कादौ A.B. चयापचयाः; U. चयापचयः

[1] In modern usage, for all the above we can simply say sin. *śīghra-kendra* is the *bhuja* and cos. *śīghra-kendra* is the *koṭi*, without taking into account the sign + or –.)

centre). Find its arc-sine. Add half this arc to the half rectified longitude of apogee if the anomaly of apsis is from 0° to 180° and subtract if 180° to 360°. Thus the apogee is rectified completely.

मध्यात् पु(न)र्विशोध्य (त)स्मादबा[हुर्न] तस्य यच्चापम् |
तन्मध्यमे क्षयधनं कर्तव्यं मन्दकेन्द्रवशात् || ८ ||

Third step

8. Substract this rectified apogee from the mean and thus get the anomaly of apsis. Find its *bhuja* and multiply it by the epicycle of the apsis and divide by 360°. The *bhuja-result*, (this is the equation of the centre), is got. Find the arc-sine of this, and subtract the whole of this arc from the mean if the anomaly of apsis is from 0° to 180°, and add it from 180° to 360°. The result is rectified mean.

एवं स्फुटमध्याख्यं शीघ्रात् संशोध्य पूर्वविधिनैव |
आदिवदा(प्तं) चापं स्फुटमध्या(ख्ये) चयापच(यम्) || ९ ||

Fourth step

9. Deduct the rectified mean from the *śīghra*. The anomaly of conjunction is got. Find the *bhuja* and *koṭi* of this in the same manner as we did in the first step. Multiply the *bhuja* by the epicycle of conjunction and divide by 360°. Sine anomaly of conj. is got. Multiply the *koṭi*, i.e., cos. anomaly of conjunction, by the epicycle of conj. and divide by 360°. The related cosine is got. Add this to 120 if the anomaly is from 270° to 90° and subtract from 120 if from 90° to 270°. Square this, add the square of the *bhuja* (i.e. equation of conjunction) and find the square root. Divide the equation of conj. × 120 by this square root. The arc sine of this is the result. Add this result to the rectified mean if the anomaly of conj. is from 0° to 180°. Subtract otherwise. The geocentric true planet is got.

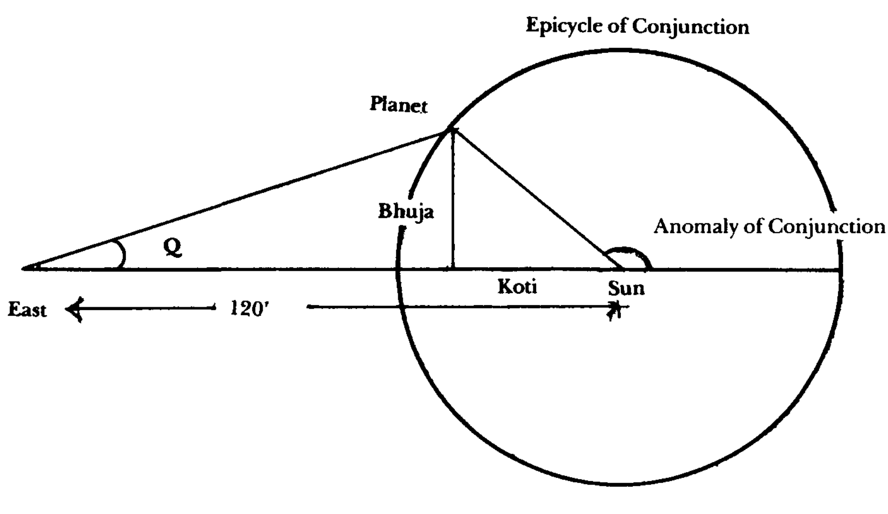
6a. A1.तद्भुज; B.तद्भुजयोग
b. A. भाजयेत्रनभू (A2.भु) जखं;
B. भाजयेत्रनभूजखं; C. विभजेद् भुजजं फलं खं;
D. भाजयेत्ततो भुजं ख
B.सूर्यघ्न्यः (B2.घ्नः)
c. A.B.तज्ञापा (B.या) र्धं
d. B.शीघ्रं B.वशतात्
7a. B.स्फुटयि (B1.पि, B3.यी) त्वैव मन्द
b. C.विशोधितस्य; D.विशोध्यं तस्य
c. B2.परिणाम B3.कामुकार्धं
d. B.धनहानिः; C.D.धनहानि
B1.2.3. repeat the verse twice and give them two consecutive verse numbers.
8a. B.मध्यासुरो A.पुरो विशोध्य; C.D.पुनर्विशोध्यः
b. A.B.C.D.तस्माद् बाहुं न
9a. a.मध्याख्यां; C.मध्याख्यान्
b. D.संशोध्यं
c. A.B.D.आदिवदाप्ते B.चाल्पं
d. A.B.मध्याख्योप (B.च) चयापचयः (B.पापचयः)

Note 1. In verse 4, I follow TS's reading, except that I have emended *ṣaḍbhyāḥ into ṣaḍbhiḥ*, instead TS's *ṣaḍbhyaḥ,* because my reading allows us subtraction or addition, as is wanted. In verse 5, I follow TS's except in the second foot, where I give the *Brihatsaṃhitā* reading. Either reading gives the same sense. In verse 6, I follow TS's except in the second foot, where I have given *bhājyam* for *vibhajet*, as being more likely. But the meaning is the same. In verse 7, the text required no emending, and TS's *dhanabāni* is unnecessary. In verse 8, like TS I have corrected *puro* into *punaḥ* but I have also corrected *bāhum* into *bāhur* which is required by grammar. In verse 9, I have corrected *madhyākhyām* into *madhyākhyam*, which is the reading of some of the manuscripts. Otherwise I follow TS.

Note 2. VM, here, as elsewhere in the *PS*, uses his tabular sine where R is 120′, as given in chap IV. So we must use his tabular values to get the R sines and R cosines. Of course, we may use the modern table, or the Siddhāntic table with R = 3438. But then the R, 1 for the modern tables, and 3438 for the Siddhāntic tables is to be used instead of 120′ which is instructed here. (VM uses *bhuja* to mean sine, and *koṭi* to mean cosine, instead using the word *jyā*).

Note 3. The method is the same as what is found in the *Later Sūrya Siddhānta*, with some changes for convenience. But in the matter of the number or order of the steps, the *Āryabhaṭīya* and the *Siddhānta-Śiromaṇi* differ. This is because, correctly speaking, the first two steps are useless, and the last two steps alone are necessary. In essence, the third serves to get the true heliocentric position, and the fourth to convert the heliocentric position into geocentric. The earlier steps are in the fond hope of getting correct positions agreeing with observation, while the real trouble is in the inexact parameters followed by the *Siddhāntas*.

Note 4. The second and third steps are merely akin to finding the equation of the centre and applying to the mean. The first and fourth steps are conversion of heliocentric to geocentric positions, neglecting the latitude, which is small and does not affect the result much. The work can be illustrated thus:



Chapter XVII. Fig. 1

The fig, is for Mercury and Venus, having the Sun as the mean planet. For Mars, Jupiter and Saturn, interchange the planet and the Sun. The geocentric position in both cases is mean planet *plus* Q. If Q is formed below the horizontal line, it is so much negative and must be subtracted from the mean.

Example 1. Find the true, i.e. geocentric, Mars at 1,20,553 days from epoch.

Given:

Mean Mars, already found with *bīja* corr. $8^r\,9°\,2'$
Śighra Mars = mean Sun of date = $0^r\,17°\,18'$
Aphelion (apogee) of Mars assumed, $3^r\,20°$ (for 120° given)
Epicycle of apsis = 70°, Apsis of conj. = 234°.

First step. Anomaly of conj. = Śīghra − mean
$= 17°\,18' - 8^r\,9°\,2'$
$= 128°\,16'$.

This is more than 90° and less than 180°.
So, subtracting from 180°, *bhujāṁśa* is 51° 44′, *Koṭiaṁsa* = 38° 16′
Bhuja = 94′ 2″. *Koṭi* = 74′ 17″
Bhuja-result = 94′ 2″ × 234° ÷ 360° = 61′ 14″
Koṭi-result = 74′ 17″ × 234° ÷ 360° = 48′ 17″
As anomaly of conj. is between 90° and 270°, this is subtractive from 120′.
120′ − 48′ 17″ = 71′ 43″.

$$120' \times \textit{bhuja-result} \div \sqrt{71'\,43''^2 + \textit{bhuja-result}^2} = \frac{120' \times 61'\,14''}{\sqrt{71'\,43''^2 + 61'\,14''^2}}$$

= 77′ 55″.
Arc for 77′ 55″ = 40° 30′
½ arc = 20° 15′
Subtracting from aphelion (since anomaly of conj. is from 0° to 180°), 110° − 20° 15′ = 89° 5′, which is the half-corrected aphelion.

Second step

Anomaly of apsis = 249° 2′ − 89° 45′ = 150° 17′
This is more than 90° and less than 180°.
So, *Bhuja* degrees = 20° 43′. *Bhujā* = 42′ 24″. *Bhuja-result* (i.e. eq. of the centre) = 42′ 24″ × 70°/360°
= 8′ 15″

Arc for this = 3° 56′; ½ arc = 1° 58′
This is additive because An. of apsis is between 0° and 180°.
Half rectified aphelion + 1° 58′ = 91° 43′ = full rectified aphelion.

Third step

The corrected anomaly of apsis = 249° 2′ − 91° 43′ = 157° 19′. The *bhuja* degrees = 22° 41′. *Bhuja* = 46′ 17″. The *Bhuja-result* = 46′ 17″ × 70°/360° = 9′ 0″ . Arc of 9′ 0″ = 4° 18′, deductive because an. of apsis is between 0° and 180°.

Mean − arc = 249° 2′ − 4° 18′ = 244° 44′ = mean corrected (for eq. centre).

Fourth step

An. conj = 17° 18′ − 244° 44′ = 132° 34′. *Bhujaṁśa* = 180° − 132° 44′ = 47° 26′, *Koṭīaṁśa* = 42° 34′. *Bhuja* = 88′ 20″. *Koṭi* = 81′ 8″. *Bhuja-result* = 88′ 20″ × 234° ÷ 360° = 57° 25″. *Koṭi-result* = 81′ 8″ × 234° ÷ 360° = 52′ 44″.

As an. of conj. is in 270° to 90°, this is deductive from 120′. So, 120′ − 52′ 44″ = 67′ 16″. 120′ × *bhuja-result* ÷ $\sqrt{bhuja\text{-}result^2 + 67'\ 16''^2}$ = 77′ 32″.

Arc of this taken as sine = 46° 16′, additive because an. conj. is from 0° to 180°.

So, corrected mean arc = 244° 44′ + 40° 16′ = 285° 0′ = geocentric true Mars.

Example 2. Find the geocentric Venus at 1,20,553 days from epoch.

Given:
The *śīghra* of Venus = 2^r 27° 16′ 20″ = 87° 16′
Mean Venus = Mean Sun = 17° 18′
Aphelion of Venus = 2^r 20° = 80°.
Epicycle of Conj. of Venus = 260°.
Epicycles of the apsis = 14°.

First step

An. Conj = 87° 16′ − 17° 18′ = 69° 58′.
The *Bhuja* degrees = 69° 58′. *Koṭi* degrees = 20° 2′.
Bhuja = 112′ 42″. *Koṭi* = 41′ 5″.
Bhuja-result = 112′ 42″ × 260° ÷ 360° = 81′ 24″.
Koṭi-result = 41′ 5″ × 260° ÷ 360° = 29′ 40″.
An. Conj. is between 270° and 90°. So the *Koṭi-result* is additive to 120′.
So, 120′ + 29′ 40″ = 149′ 40″.
Bhuja-result × 120′ ÷ $\sqrt{81'\ 24''^2 + 149'\ 40''^2}$ = 57′ 20″.
Arc 57′ 20″ = 28° 33′. Half arc = 14° 17′, subtractive to aphelion (as An. conj. is from 0° to 180°
80° − 14° 17′ = 65° 43′ = Half corrected aphelion.

Second step

An. of apsis = mean − half cor. aphelion = 17° 18′ − 65° 43′ = 311° 35′.
The *Bhuja* degrees are 48° 25′.
Bhuja = 89′ 44″.
Bhuja-result = 89′ 44″ × 14° ÷ 360° = 3′ 29″.
Arc. 3′ 29″ = 1° 40′. Half arc = 50′, subtractive, as an. conj. is from 180° to 360°.
Corrected aphelion = Half-corrected aphelion − 50′ = 65° 43′ − 50′ = 64° 53′.

Third step

An. of apsis = mean-corrected aphelion
= 17° 18′ − 64° 53′ = 312° 25′
Bhuja degrees = 47° 35′. *Bhuja* = 88′ 33″.
Bhuja-result = 88′ 33″ × 14° ÷ 360° = 3′ 27″.
Arc sine 3′ 27″ = 1° 39′, additive as an. of apsis is 180° to 360°.
So, mean Venus + arc = 17° 18′ + 1° 39′ = 18° 57′, is the eq. cent. corrected mean.

Fourth step

An. conj. = *Śīghra*-corrected mean
$= 87° 16' - 18° 57' = 68° 19'$.
Bhuja degrees = $68° 19'$. *Koṭi* degrees = $21° 41'$
Bhuja = $111' 29''$. *Koṭi* = $44' 19''$.
Bhuja-result = $111' 29'' \times 260° \div 360° = 80° 31'$
Koṭi-result = $44' 19'' \times 260° \div 360° = 32' 0''$.
As an. conj is from 270° to 90°, additive to 120°. So, $32' 0'' + 120' = 152' 0''$.

$\textit{Bhuja-result} \times 120 \div \sqrt{\textit{Bhuja-result}^2 + 152^2} = 62' 12''$.
Arc sine = $62' 12''$. Half arc = $31° 14'$, additive as an. conj is 0° to 180°.
Geocentric true Venus = $18° 57' + 31° 14' = 50° 11'$.

In verse 11 below, VM requires us to subtract 67′ or 1° 7′ constant, as bīja-correction, after all work is over. So, geocentric True Venus = $50° 11' - 1° 7' = 49° 41'$.

[बुधशुक्रयोः विशेषक्रिया]

सर्वे स्फुटाः स्युरेवं ज्ञस्य तु शीघ्राद्विहाय रविमन्दम् ।
रविपरिधिनतं बाहुं (बुधेऽर्कवत्) क्षयधने कुर्यात् ॥ १० ॥
शुक्रस्य सप्त(षष्टि)र्लिप्ताः शोध्याः स्फुटीकृ(तस्यै)व ।

Special work for Mercury and Venus

10. All star-planets are (geocentrically) made true in the above manner. But in the case of Mercury, this additional work is to be done: Subtract its apogee from the *śīghra* and, using the Sun's epicycle, find the *bhuja*-result and apply it to the mean Mercury (which, of course, is the same as the Sun's), with the addition or subtraction done, as the Sun's *bhuja*-result is additive or subtractive.

11 a-b. From Venus, subtract 67′, constant, after all the earlier *sphuṭa* work instructed has been done.

Note 1. The reading *kṣayadhane* is better as it is, and TS need not have corrected it into *kṣayadhanam*. The reading *budhavat* is deficient by two syllables, Lalla's reading *budherkavat* supplies these and makes the meaning more clear. So I have adopted it. TS's emendation *budhaphalavat*, with *phala* added for the two *mātrās* wanting, is not different in meaning from *budhavat*. Being an arbitrary rule, we cannot decide which gives the original meaning, *budherkavat* or *budhavat*. But since Lalla's reading is not defective, at least as far as the *mātrās* are concerned, I have adopted it.

10a. B. om स्फुटः B. कारेवं
b. A2. ज्ञस्य पुर्शीं; B. ज्ञेक्यं ध्रुशीघ्रा; D. ज्ञेड्येषु शी
c. A2. बाहु; B. वाग्दं
d. A.B. बुधवक्ष; C. बुधफलवत्; D. बुधे (क) व(ौ) क्षयधनं

11a. A. व्यष्टिः; B. व्यष्टि
b. A.B. शोध्या A. स्फुटिकृतस्यैव; B. स्फुटितस्यैव
(B2.3. ०त तस्यैव)

Also, it is clear that it is not a substitute for any of the four steps because, if so the separate epicycle for Mercury will be useless.

Note 2. It is clear that the rules given here are VM's own, to secure, in his opinion, better agreement with observation, because they are not given in the *Ārdharātrika-pakṣa* etc. and the original four steps are all in line with them, as also the modern *Sūrya-Siddhānta* and the *Siddhānta Śiromaṇi*.

Note 3. The whole work of finding the true positions, especially of the star-planets is defective in Hindu astronomy, in that the equation of the centre of Hindu astronomy neglects the second, third, etc. terms, which is considerable in the case of the Moon, Mars, Saturn and Mercury, in which last case the second term is as large as 3°. In the case of Mercury and Venus it is applicable to the Sun, instead of their *Śīghra* which is really their mean. In the equation of conjunction, the Sun's true distance from the earth and true longitude should be used, instead of the mean distance and mean longitude, as is done in Hindu astronomy. On account of these defects, computation does not agree with observation, and all sorts of hotch-potch rules are given in different astronomical works. The disagreement among themselves would itself show that they are beside the mark. When these defects are remedied, the third and fourth steps alone would be necessary, the third step giving the heliocentric true planet; and the fourth step converting the heliocentric position to the geocentric.

Note 4. In the case of Venus, there is another kind of defect. Its maximum eq. of cent. being small, it is confused with the Sun's, and the Sun's epicycle and apogee are given to Venus also. While its aphelion position is 290°, according to modern astronomy, its apogee is given as 80°, the same as the Sun's.

Table of Heliocentric Star-planets at epoch. (For mutual comparison)

Planets	*1* *Modern astronomy*	*2* *Sidd. Śiromaṇi*	*3* *Later Sūrya Siddhānta*	*4* *Earlier S. Siddhānta* of *PS*	*5* *Vāsiṣtha Pauliśa* of *PS*	*6* *Interpolation* in *PS* XVIII
Mercury	151°	148½°	166°*	148°		161½°
Venus	269°	268½°	264°	267°	269½°	269½°
Mars	75°	76½°	78°	75½°	83½°	83½°
Jupiter	9°	9½°	9°	8°	12 °	9 °
Saturn	122°	122 °	123½°	122½°	120 °	118 °

For values in column (5) see their derivation in the Notes to ch. XVIII. All values have been computed by me.

* This needs explanation: Perhaps the reading is *śūnyāśvi* in *Sūrya Siddhānta* I.31, which will reduce the degrees by 12. But the commentator Raṅganātha takes it as *śūnyartuḥ*.

Table of Synodic periods of the Star-planets

Planets	1 *Mod. Astr.*	2 *Sid. Sir.*	3 *Later Sū. Siddh.*	4 *PS-Sū. Siddh.*	5 *PS-Vās.-Pauliśa*	6 Interpolated *PS XVIII*	7 Ptolemy
Mer. 115.	87747766	8784290	8780110	8785195	8791307	8750556	.879
Venus 583.	92136655	8968279	9001782	8975750	9092440	9060301	584.000
Mars. 779.	93610175	9222494	9242712	9211734	9553326	9787326	.943
Jup. 398.	88404760	8894794	8891768	8891698	8891358	8852917	.886
Sat. 378.	09190150	0859936	0863874	0860183	0997090	1100185	.093

All values except those in column (7) have been computed by me. In column (6), the solar 'days' given have been converted into ordinary days.

[वक्रग्रहाणां स्फुटाः]

वक्रानुवक्रकालो भुक्तिविशेषेण विज्ञेयः || ११ ||

Retrograde motion

11 c-d. The times from the beginning of the retrograde motion to its end and the follow up period can be found by the daily motion (being negative, during this period, and the convention regarding these).

Note: The terms *vakra* (retrograde) and *anuvakra* (follow-up at the end of retrograde) are technical. They are eight in number according to the *Sūrya Siddhānta*, given by the verse:

vakrātivakrā kuṭilā mandā mandatarā samā/
tathā śīghratarā śīghrā grahāṇām aṣṭadhā gatiḥ//

The generally given reading *vakrā-anuvakrā* is wrong in my opinion and I have read it as *vakrā-ativakrā*, and *ativakrā* has taken the place of *anuvakrā* in the verse. The expression *yā vakrā sā'nuvakragā* in the next verse makes it clear.

Generally the near ones are subsumed into one another. But in the case of Mars, VM gives all these eight and their degrees and periods. See below under XVIII. 33-34.

[ग्रहोदयकालभागाः]

स्फुटदिनक(रान्तरां)शाः चन्द्रादीनां च दर्श(ने) ज्ञेयाः |
(विं)शति(रू)ना 'वसुशिखिमुनिनवरुद्रे(न्द्रियैः)' क्रमशः || १२ ||

11c-d. A. वक्तानु. B. विशेण ज्ञेयः

Heliacal rising of the planets

12. The heliacal rising and setting of the Moon, Mars, Mercury, Jupiter, Venus and Saturn are when their elongation (from the true Sun) are 12°, 17°, 13°, 11°, 9°, and 15°.

Note 1. I generally adopt TS's readings. But *Śaśi* is extra, and evidently a mistake which has crept into the reading. To make up for this they have removed *rudra* which is necessary, and this emendation has spoiled the correct agreement with other *siddhāntas*.

Note 2. These are time-degrees, i.e. time expressed in degrees (*kālabhāga*) and are arbitrary in essence, and depend on the keennees of the observer's eyesight, as also the atmospheric conditions. The later *Sūrya-Siddhānta* gives 10° and 8° for Venus at superior and inferior conjunctions, and 14° and 12° for Mercury, respectively, while the *Sūrya-Siddhānta* here and some others give the mean of each. (The *Mahābhāskarīya* gives even 4° or 4½° for Venus at inferior conj. and 8° at superior conj.)

[ग्रहविक्षेपाः]

मन्दग्रहान्तरज्या स्वाष्टांशयुताऽर्किजीवशुक्राणाम् |
सौम्यान्ययोः पदो(ना) विक्षेपोऽन्यश्च शीघ्रविधौ || १३ ||
गुरुभूतनयाऽऽस्फुजितां पादोना (ज्ञयमयोस्तु सा)ष्टांशाः |
त्रिज्याघ्नी कर्णाप्ता (वि)यो(गाश)विक्षेपः || १४ ||

Latitudes of planets

13. Add one eighth of itself to the R (120′) sine of (mean planet − apogee), in the case of Saturn, Jupiter and Venus. For, the two others, (i.e., Mercury and Mars), subtract one fourth of itself. (This is one part of latitude). There is another part of latitude using the Anomaly of conjunction.

14. From the R sine anomaly of conjunction of Jupiter, Mars and Venus subtract one fourth of itself. From that of the rest, (viz., Mercury and Saturn) add an eighth. Add both algebraically and note the direction, north or south. Multiply this by R (i.e. 120′) and divide by the hypotenuse got in the last step. The latitude is got, its direction being that of the noted direction.

12a. A. स्फुट दिनकरांतरांतरांशाः; B. स्फुरदिनकरांतरांतराशाः
b. A. च दर्शनी ज्ञेयाः; B. व दर्शज्ञेयाः
c. A.B. विशतिरु (B. रू) ना
d. A.B.C. वसु शशिशिखि A. रुद्रेदियैः; B. रुंद्रेद्रिणैः; C. नवकेन्द्रियैः
13a. B. ग्रहातरज्या (B2. नरज्या, B3. तरुज्या)
b. B. स्वाष्टांशसुर्किजीव॰; D. युता कुजेज्यशुक्राणाम्
c. B. सौम्यपन्योः; D. सौम्यारयोः A. पदोनां; B1.2. पदनां
d. A. विक्षेपोन्पश्च
14a. B. गुरुभूततया
b. B. पदोना A. ज्ञयममयोमुशांष्टांशाः; B. ज्ञयमयोमुष्ट्यंशां C. ज्ञमयोश्च C.D. साष्टांशा
c. B. कर्णप्ता A. नियोगयोशम विक्षेपः; B. नियोगशास विक्षैपः; C. वियोगजाशः स विक्षेपः; D. वियोगयोगः स विक्षेपः

Note 1. This is a peculiar primitive way of finding the latitude of the star-planets. It is not found in the allied *Khaṇḍakhādyaka* and the quoted part of the Bhaṭṭotpala-quoted *Pauliśa*. It is found in Āryabhaṭa's *Ārdharātrika-pakṣa* given in the *Mahābhāskarīya* (VII. 28-33). But there are some differences between the two, and we cannot decide which follows the original *Saura* here, and which has slightly modified the original. They both mention two kinds of latitudes for each star-planet which are to be added algebraically. But there is a difference in the maximum latitudes, and in the ascending nodes to be subtracted from the mean longitudes or *śighras*. VM's *Saura* implies the max. latitude 90′, 90′, 135′, 135′, and 135′, for Mars, Mercury, Jupiter, Venus and Saturn, respectively, to be multiplied by sine anomaly of conjunction, and 90′, 135′, 90′, 90′, and 135′ to be multiplied by sine anomaly of conjunction, no separate node being given, which means that the apogee itself is the node for one kind of latitude, and the mean planet itself for the other. But the *Ārdharātrika* gives only one set of maximum latitudes for both, viz., 90′, 120′, 60′, 120′, 120°. It gives the nodes, 20°, 40°, 70°, 260°, and 150° for the former and 20°, nil, 70±, 260° and 150° for the latter. *Govindasvāmi's Bhāṣya* on the *Mahābhāskarīya*, being meagre, does not help us.

Note 2. By implication, we had better take the arguments of the eq. cent. used in the third step for the former, and the anomaly of conj. used and hypotenuse obtained in the fourth step for the latter.

Example: Find the latitude of Mars at 1,20,553 days from epoch.

In the third step of the earlier example, the sine of the argument of eq. conj. is 42′ 24″. As it is Mars, deducting quarter of itself, the latitude is 31′ 48″, north, as this argument is between 0° and 180°. In the fourth step, the sine of the argument of conj. is 88′ 20″. For Mars one fourth is to be subtracted. So, the latitude due to this is 66′ 15″, again north, since the argument is from 0° to 180°. Adding, 31′ 48″ + 66′ 15″ = 98′ 3″, north.

The hypotenuse obtained there, in the fourth step, is 88′ 52″.

98′ 3″ × 120 ÷ 88′ 52″ = 132″ north, is the true latitude of Mars for the day.
(As it is, this is far from the latitude obtained from using the later *Siddhāntas*.)

Note 3. The treatment of *Saura* is taken up by VM in XVIII. 57-60, where the latitude found here is used to correct the mean elongation given in verse 12, for the heliacal setting and rising. The exposition of these verses is given in XVIII.

[इति पञ्चसिद्धान्तिकायाम् वराहमिहिरविरचितायां
ताराग्रहस्फुटीकरणं नाम सप्तदशोऽध्यायः ||]

Thus ends Chapter Seventeen entitled 'Saura-Siddhānta – True Planets' in the Pañcasiddhāntikā composed by Varāhamihira

Col.: A.B.D. ताराग्रहस्फुटीकरणं षोडशोऽध्यायः;
C. इति ताराग्रहस्फुटीकरणं नाम सप्तदशोऽध्यायः

Chapter Eighteen

(VĀSIṢṬHA-) PAULIŚA-SIDDHĀNTA — RISING AND SETTING OF PLANETS

अष्टादशोऽध्यायः
वासिष्ठ-पौलिशसिद्धान्तौ — ग्रहोदयास्ताधिकारः

Introductory

Chapter XVIII of *PS* (NP's ch. XVII) deals primarily with the star-planets according to the *Vāsiṣṭha* and *Pauliśa siddhāntas*. The true motion of the planets is traced from one heliacal rising to the next. The method of getting the true anomaly of the equation of the centre is similar to that of the Moon given by the *Vāsiṣṭha* in ch. II and based on the same theory of the rate of motion, forming a linear zigzag. Even the same technical term *pada* is used here. All these are reminiscent of the Babylonian astronomy of the Selucid period. The text as available too is not very pure and this too has made the interpretation of this chapter difficult for TS. In my paper on 'Some misinterpretations and omissions of Thibaut and Sudhakara Dvivedi in the *PS* of VM' (*VIJ*., 11 (1973) 107-18) I have indicated the errors occurring in the said publication. NP have improved upon TS's interpretation in some places, but have committed worse mistakes in other places. TS and NP have also failed to understand how the equation of the centre has been computed and applied to the equation of conjunction of Jupiter and Saturn. Since they had to interpret, in some way or other, the related verses, they have altered the verses, in all sorts of ways, to yield what they thought the meaning *might be*. Even in the case of Venus, where computation has been made simpler by neglecting the small equation of the centre, they have committed several errors which have been pointed out in the exposition of these verses given below.

[शुक्रचारः]

हित्वा '(जलमुनि)चन्द्रा(न्)' द्युगणाद् 'वेदाष्ट-भूत'हृतलब्धाः |
शुक्रोदया गुणाप्तैः सार्धाः पञ्चालिनो भोगाः || १ ||

कन्यांशा[न्] षड्विंशतिमित्वा शुक्रोऽपरेण या[त्यु]दयम् |
उदयैकादशभागान् दिनेषु दत्वा तत[श्चा]राः || २ ||

Motion of Venus

1. Subtracting 174 from the days from epoch, the quotient got by dividing the remainder by 584 are the heliacal risings of Venus. Its motions during the periods is $7^r\ 5°\ 30'\ 20''$ each.

2. Having gone to 26° of Virgo, i.e. at, $5^r\ 26°$, Venus rises in the west (for the first time after epoch). Adding an eleventh of the quotient (given in verse 1) to the remaining days, the motions (are to be taken from the Table given in verses 3-5).

174 days after epoch, Venus rises heliacally in the west. We have emended *munijala* as *jalamuni* because 147 will not agree with the longitude of Venus at rising given as 5^r 26°. If Venus is 5^r 26°, the sun must be 5^r 18°, to satisfy the 8° given for Venus's heliacal risng in verse 58. But since at epoch the sun is in the neighbourhood of 358°, it can be only near 4^r 25° after 147 days, i.e., 38° from Venus. After 174 days from epoch, the Sun would be near 169° according to the *Vāsiṣṭha-Pauliśa*. (Vide my paper 'The epoch of the Romaka etc.', *Indian Journal of History of Science*, 13 (1978) ii. 155-58). This gives the elongation as 7° instead of the required 8°. But this small discrepancy can be put to an accumulated error in computing from the original. TS have not felt the need for this emendation because they have emended *kanyāṃśān* into *kālāṃśān* and omitted the necessary *kṣepa* viz. the constant equal to 5^r 26°, for beginning the motion. They have not understood the meaning of the word *kālāṃśān* which they have brought in. It is the same as the 8° mentioned above, for Venus. NP have interpreted *kanyāṃśān* correctly. But since they have kept 147 days to be deducted intact, they find a serious discrepancy expressed by them on page 124 of Part II. However, they derive satisfaction from the fact that the September 10th position of the sun would agree with the time of Venus's rising and their longitudes. This at least must have shown them that the rising takes place only more than 20 days later. They have made all sorts of unnecessary emendations, but they have failed to do this necessary one.

We can infer from the instruction to add an eleventh of the quotient, that one synodic revolution takes 583 10/11 days. In this period the sun has moved 1 revolution 7^r 5° 30′ 20″ and Venus, 2 revolutions 7^r 5° 30′ 20″. From this we can infer that the sun takes 365-15-25 days for a sidereal revolution. From the methods given for the other planets also we can see that the sidereal period of the sun used is *c*. 365-15-30, which is an evidence for the system given here being connected with the *Pauliśa* also, as in the case of the Moon.

TS have unnecessarily emended *bhogāh* into *bhāgāḥ* and taking *sārdhāḥ* to mean 'together with', instead of 'with half', have given a motion of 7^r 5° 20′ per synodic period. They are unaware that this would make the sidereal year *c*. 365-22 days, so wrong. The error of 10′ 20″ in Venus would accumulate by 1° every nine years.

NP interpret *sārdhāḥ* correctly, but take *guṇāptaiḥ* to mean 'with 1/3 degree' and given 7^r 5° 50′, which would make the sun's sidereal year *c*. 365-3-0, so very wrong. By this the error in Venus would accumulate by 1° in every 5 years.

Next the days for segments of motion in the synodic cycle are given by verses 3-5.

षष्टि[र]येण 'वेदाग्नि-यम-'युतामंशसप्ततिं भुङ्क्ते |
(अर्था)ष्ट[कैर्द्धा](त्रिंशतं) विंश(त्या) [वि]त्रिभिः सपा'(दार्थान्)' || ३ ||

1. A.B.C.D. मुनिजल (B. जाल). A.B. चंद्रा
b. B. ॰ष्टमूत. A2. दूत corrected to हत; B. हत
c. A. शुक्रेदया. C. गुणांशैः; D. गुणांशाः
d. A. सार्द्धां; B. सार्धा
B1.3. पंचलिनो; B2. पञ्चालिनो. C. भागाः;
D. भोगः

2a. A.D. कन्यांशाः; B. कन्याशाः;. C. कालांशाः
B. षड्वति
b. A1. यात्फदयं; A2. यात्पुदयं
c. B. उदैका. C.D. भागं
d. A.C. सतस्ताराः;. D. ततश्र्चारः

वक्रमतस्तिथिभिर्द्वौ पञ्चभिरेवं ततोऽपरास्तमितः |
दशभिः प्रागुदितः स्यान्नखैश्च जलधीन् मि(तान्) गत्वा || ४ ||

अनुवक्री परिगत्वा विपरीतमस्तमैत्यै(न्द्र्याम्) |
षष्ट्यांशपञ्चसप्ततिमित्वाऽपरतो भृगुर्दृश्यः || ५ ||

|| वसिष्ठसिद्धान्ते शुक्रः ||

Days for segments of motion in the synodic cycle

3. In three periods of 60 days Venus moves 74°, 73°, 72°, respectively. In 40 days it moves 32° and in 17 days, 5¼°

4. From here retrograde motion (begins). In 15 days these are 2°; in 5 days the same, i.e., 2°. Then, setting in the west, it rises in the east after ten days. Venus is in follow-up retrograde for 20 days, moving 4°.

5. Then continuing the (direct) motion round, in the order of days and motions reversed, Venus sets in the east. Then moving 75° in 60 days, it becomes visible in the west.

The argument to be used in the above table of motions are the days left over, together with the eleventh of the quotient, as mentioned. It can be seen that in my emendations of some of these I have done very little violence to the text. I have been guided in these by the actual motion that must have been observed, putting it to observational or other error, where the numbers are clear, but deviate from the actual. The ratio of Venus's distance from the sun to the earth is *c.* 0.72 given by all Hindu and modern astronomy, and this I have used to compute the segments of actual motion for comparison. (See Table on next page)

Another guide is that the days and motions from the superior to the inferior conjunction must add up to half of the whole, i.e., 292 days, and 287¾°, since the equation of the centre has been dispensed with.

72° motion for the third 60 days is about 4° in excess. For the next 40 days the motion has to be 36°, and I could have filled up the lacuna by (*khaissat*) instead of (*khairdvā*) to get this. But the *Siddhānta* seems to have compensated the earlier 4° excess by the 4° defect here, which of course is an error. From this we can see that the emendation of *'dvimśat'* into *'trimśat'* is necessary lest the motion be reduced to 26°, which is too small.

3a. A.B.C.D. षष्टित्रयेण
B. सेसाग्नि
B. मंशसप्त | ति; B. साप्तति भुक्ते
c. A1. अर्धाष्टकेन विंशति (A1. om क्रेन);
B. अर्धाष्टकेन विंशतां (B2. विंशति)
C. अर्धाष्टकेन सप्त; D. अर्धाष्टकविंशत्या
d. A.B. विंशत्यैस्त्रिभिः सपादांशं;
C. सप्तत्यंशांस्त्रिभिः सपादांशम्;
D. विंशत्यं [शका] स्त्रिभिः सपादांशम्

4a. B. वक्रमतं स्त्रितिभिः
d. B. स्यान्तरवैश्च
A. मिता गत्वा; B. मिता गता;
D. सितो for मितान्
5. B. verse missing
5a. C. दन्तकरैः for परिगत्वा
b. A1. मस्तमत्यैड्यां; A2. मस्तमत्पैड्यं;
C. रवशरयमानस्तमेत्यैन्द्रयाम्;
D. विपरीतं चास्तमेत्यैन्द्रयाम्

TABLE I

Motion on the synodic circle (computed)

Superior conjunction		**Retrograde begins**		**Retrograde ends**	
30 days	37½°	9 d.	−2¼°	243 d.	258 °
Rising West		5 d.	−2½°	Setting East	
60 d.	74 °	Setting West		30 d.	37½°
60 d.	73 °	5 d.	−2½°	Superior conjunction	
60 d.	68¼°	Inferior conjunction		Total 514 d.	575½°
27½ d.	26¼°	5 d.	−3°		
12½ d.	9¼°	Rising East			
17 d.	7 °	5 d.	−2½°		
6 d.	¼°	9 d.	−2¼°		

Next, 1¼° for 23 days is too too small to be correct. Further, the correct total of days and degrees clearly given by the numbers will be spoiled by this. So I have given the meaning as 5¼° in 17 days, which fairly agrees with the actuality, by introducing a (*vi*) for the defect of two *mātrās* and emending *sapādāṃśam* into *sapādārdhān*.

Since the motion only 15′ for the 6 days near the stationary point as seen in the actual, the *siddhānta* is justified in combining this with the −2° 13′ for the next 9 days and giving −2° for 15 days. But, for the next 5 days, the motion is almost −2½° and not −2°, and this is an observational error. For the 5 days forming the half period of invisibility till the inferior conjunction, the actual motion is about −3° but we are constrained to make it −2° for agreement with the other numbers, especially when it is left to be understood, no motion being given by the text. A glance at the comparative table will make everything clear.

TS have made the serious mistake of thinking that the segments given begin with the superior conjunction instead of the rising on the west (vide the scheme given in the Sanskrit Commentary, p. 98). By the total of 610 days, they have given that the rising takes place 26 days after superior conjunction, passing 22½°, which is absurd because it should be 37½° in 30 days, i.e. half the time and degrees given for the time from setting to rising. They do not realise that this is the period of the quickest motion. Within the scheme they get the 77° for 85 days, by making a drastic change in the wording of the text. Further, for 85 days in that part, the motion would be more than 91°. Giving 1¼° for 3 days near the stationary point is wrong since it should be practically zero. −4° for 5 days in retrograde is too great. But they have given the same −4° for the 10 days in the *ativakra* region where the rate should be the greatest.

As for NP, they have correctly interpreted that in the three 60-day periods after rising, the motions are 74°, 73° and 72°, that from setting in the east and rising in the west there are 75° for 60 days, half before the superior conjunction and half after, and that near the inferior conjunction there are 50 days of retrogression and −12°, half of each falling on each side of the point, as given by the text. Adding these we can account for 250½° in 235 days. Since we should get 287¾° for the 292 days from the superior to the inferior conjunction, we have still to account for 37¼° in 57 days. This we must seek in the second half of verse 3. By some likely emendations we can secure this, as I have done. But NP have drastically changed the text as

arthāṣṭakaviṃśatyā viṃśatyaṃ(śahā)stribhis sa pādāṃśam,

also sinning against prosody, and given only 28° for the 27½ days, after the third sixty-day period, and 1½° for the next 3 days, thus, not accounting for 16° and 30½ days.

ardhāṣṭakaviṃśatyā cannot mean 27½, besides being an un-Sanskritic formation. Further, for the 27½ days in that part of the synodic circle the motion should be more than 26° and for the next 3 days, more than 2¼° as can be seen by examining the actual. This error of 16° and 30½ days is doubled for the whole cycle, and the weight of this error of 32° and 61 days has been carried by them to the 60-day period of invisibility and drawn the remark on page 121, Part II: "a rather implausible conclusion. At any event, the description of the motion of Venus as given in our text seems incomplete." The footnote here is uncalled for.

Jupiter and Saturn

The computation of Jupiter and Saturn follows next to Venus. This is because their treatment is next simple, on account of their small mean motion and equation of conjunction, owing to their great distance. Both TS and NP have expressed inability to understand the part of the computation where the equation of the centre is obtained and applied, before the application of the eq. of conjunction. Still, they have attempted to interpret the concerned verses, changing the wordings, drastically, to yield their fancied ideas. In getting the eq. of conj., too, they have made several mistakes.

As in the case of Venus, here too, the true motion is traced from one heliacal rising to the next. The method of getting the true anomaly of the eq. cent. is similar to that of the moon given by the *Vāsiṣtha* in chap. II, and based on the same theory of the uniform increase and decrease of the rate of motion, forming a linear zigzag. Even the same technical term, *pada*, is used here. All these are reminiscent of the Babylonian astronomy of the Selucid period, as I have stated above. As between Jupiter and Saturn, their treatment is exactly similar, so that explaining one would suffice for both. Verses 6-13, deal with Jupiter and 14-23 with Saturn. My main aim here is to state and explain the procedure in the computation, a thing not understood by investigators. The verification of the epoch constants depend mainly on comparison with other systems and modern astronomy. So this will be done separately.

[गुरुचारः]

विचतुस्त्रिंश(द्युग)णं नाडीभिस्तावताभिरपि च गु(रोः) |
(हृ)त्वा 'नव नव दहनै' (रु)दया लब्धा(स्स्थि)ता दिवसाः || ६ ||
उदयनवां(शं) दत्वा दिनेषु षड्वर्गसंगुणैरुद(यैः) |
एकनवाग्नि(च्छिन्नैः) (प)दमिति साष्टादशं शेषम् || ७ ||

Risings of Jupiter

6. The days of Jupiter from epoch minus 34 days, 34 *nāḍikās* divided by 399, give the number of risings. The remaining are days (after rising).

7. Add to these days a ninth of the number of risings. Multiply the number of risings by 36, add 18, and divide by 391. The remainder here are *padas*.

We can conclude the following from these two verses:

(i). At 34 d. 34 n. from epoch, the first period from rising to rising begins.

(ii) The interval between the risings, i.e., the synodic period is 399 − 1/9 = 398 8/9 days.

(iii) 391 *padas* make one full sidereal revolution of Jupiter, i.e., 360° of mean motion. In one synodic period, Jupiter moves 36 *padas*. One *pada* = 55′ 15″. 36 *padas* = 36° 9′. At epochal days 34 d, 34 n, Jupiter's longitude is 18 *padas* (= 16° 35′). But NP have taken the 18 given here as degrees. This is wrong. The difference of 1° 25′ is too small to show itself in their verification, Table 32, Part II. But for Saturn this *pada* constant is 89, and for Mars, 85. Taking these as degrees have resulted in big differences which have puzzled them. See part II, page 124.

(iv) In 391 syn. revolutions there are 391 + 36 = 427 solar sidereal revolutions = 36 Jupiter's sid. revolutions. ∴ one sid. rev. of Jupiter takes 4332-22-48 days, and one sid. rev. of the sun = 365-15-32 days. The latter being very near Pauliśa's 365-15-30, we conclude that, there too, as in the Moon, it is mixed up with the Vāsiṣṭha's.

TS and NP give the same interpretation, though making more than necessary emendations. In their verification, TS use the rough syn. period of 399 days instead of the correct 398 8/9, making the sid. period = 4333-35-0.

क्रमशो म(ध्यः) स्फुटश्च खण्डौ [कार्यौ] त(यो)-श्च वि (श्ले) षात् |
स्फुटहाना द्युषु दद्या (न्मध्यात्) सौ (र्ये) ऽन्यथा हानिः || ८ ||

8. One after another, mean and true segments are to be arranged. Taking their difference, if the true is less than the mean, the difference is to be added to the group of Jupiter's days (left over in the synodic cycle as the remaining days). Otherwise, (i.e., if the true is more), the difference is to be subtracted.

'True' here means 'true as corrected for the eq. of the cent'. How to get these true positions is given in verses 9-11, and the segments are to be got using these. So, this verse seems to have strayed here from after verse 11. The mean positions are to be got by using the remaining *padas*, extending the work done in verse 7.

Kāryau is introduced to make up for the syllables wanting. *Saure* would mean 'pertaining to either Sun or Saturn'. But we are dealing with Jupiter Sūriḥ here. *Saurya* alone would mean, 'pertaining to Jupiter'. Some mss. have no *dvi*.

Computing and arranging the mean and true segments against each other is to facilitate interpolation to any required day. It will also be useful to prepare an ephemeride. The example worked will make things clear.

6a. A1. विवतु; A2. विवनु C.D. त्रिशद्. A.B. द्विगुणं
b. A.B.C.D. तावतीभिरपि. A.B. गुरुः
c. B2.3. Unindicated om. of नव [नव....प) दमिति in 7d.
d. A1. तुदया; A2. नुदया; B. om. line. A. ०स्थिदिवसाः
7a. A. उदयरवांशं; B. a-c. missing. C.D. उदयनवांशान्
b. C.D. गुणे ह्युदये. A. ०रूदयः
c. A.C.D. छिन्ने
d. A. वदमिति; B. ०मितिः. B1.3. साष्टदशं
8a. A.B. द्विक्रमशो; C. द्विः क्रमशो; D. द्वि [हितः] क्रमशो A. पव्यस्फुट
b. A.B.C. खण्डैस्तयोश्च (A. थौश्च) विशेषात्; D. खण्डस्तयोश्च विशेषात्
c. A.B.C.D. स्फुटहानौ B2. द्यूयु
d. A. तध्यत्सौरैन्यथा; B. तत्सौरैन्यथा; C. मध्यात् सौरऽन्यथा; D. त [न्म] ध्यखण्डेऽन्यथा

TS have expressed doubts about their translation, since they have not understood verses 9-11. They have retained *hi*, not supplied the wanting *mātrās*, and not noticed the grammatical error in *Saure*. NP have made three drastic emendations, quite unrelated to the lettering of the text, *nihitaḥ:*, *maṇḍalaḥ:* and *tanmadhya-khaṇḍe*, though generally following TS.

‘रसविषयकृतशशाङ्काः’ क्षयखण्डे ‘(ख)धृतयः’ पदं यावत् ।
‘विषय’(रसेशा) वृद्धौ जीवः स्यात् पञ्चनवतिशतात् ॥ ९ ॥
‘षड्वसुमनवो’ हानौ तृतीयखण्डे गुरुस्तु षोडशके ।
प(द)गुणिते त्र्यष्टकभाजिते कला पूर्वतोऽभ्युदिते ॥ १० ॥
नव सार्धाः कन्यांशाः प्रथमे खण्डे द्वितीयखण्डे (स्युः) ।
चक्रार्धं च(युगां)शाः दश(च) कला देवपूज्यस्य ॥ ११ ॥

9. Jupiter being in the diminishing-motion-sector upto 180 *padas*, there is the constant 1456 (to work with, in order to get the eq. cent-corrected-Jupiter). Being in the increasing-motion-sector in the next 195 *padas* (i.e. 181 to 375), there is the constant 1165.

10. Jupiter being in the diminishing-motion-sector (again) in the next 16 *padas*, there is the constant 1486. (After subtracting or adding the *padas* for which we want computation from these numbers, in the respective sectors), multiplying them by the *padas* and dividing by 24, minutes of arc are got, (as the eq. cent. corrected total motion in the respective sector) at the rising in the east (and also thereafter if wanted).

11. The total of such motion of Jupiter in the first sector is $5^r\ 9°\ 30'$. In the second sector, it is $6^r\ 4°\ 10'$.

Briefly expressed as formulae, the eq. cent. corrected Jupiter is given by:

i. If *padas* are from 0 to 180, (1456 −*padas*) × *padaś'* ÷ 24.

ii. If *padas* are in the next increasing sector, i.e. from 181 to 375, (1165 + *padas*) × *padas'* ÷ 24 + 5' 9° 30', where the *padas* used are those given in that sector.

9a. B.रसा
b. B. Hapl. om: खण्डे [खधृतयः.... खण्डे] गुरुस्तु (10b)
A.विधृतयः
c. A.रसोना; C.D.रसेना
d. A.पवंनवति
10b. B.शोडशके
c. A.B.C.पञ्चगुणिते; D.पञ्चविगुणिते
B.°ते अष्टकभा; C.°तेऽष्टकभा; D.°ते त्वष्टभा
d. A.B.C.D.कलाः. A.B.1.2.°भ्यदिते; D.°भ्युदेति
11b. A.B2.3.खण्डे स्फुः
c-d. B1.2.3. missing.
c. A.चक्रार्धे व गुणाशा; C.चक्रार्धं च गुणाशाः; D.चक्रार्धं द्विगुणांशाः
d. A.दश श कला; C.परशकले; D.दश सदला

iii. If the *padas* are in the next following sector, i.e. 376 to 391, (1486 – *padas* × *padas*′ ÷ 24 + 5^r 9° 30′ + 6^r 4° 10′, where the *padas* used are those gone in that sector.

Though the instructions are laconic, comparison with the Moon's computation makes things clear. The increasing-motion sector is obviously the 180° from apogee to perigee, where the rate of motion is supposed by this *siddhānta* to increase uniformly from a minimum to a maximum. The apogee is at 180 *padas* (= 166°) and the perigee at 376 *padas*(= 345°). The last 16 *padas*, continued by the first 180 *padas* form the diminishing half circle where the rate of motion diminishes uniformly from the perigee to the apogee. Differentiating the formula, (constant ∓ pada) pada′/24, the increase or decrease in the rate of motion is found to be 2′/24 = 1′/12 per *pada*. There may be a small hiatus at the junction, apogee and perigee, owing to the unequal division of 391 into 196 and 195, to avoid half *pada*. But the average of the rates at apogee and perigee, (1165′ and 1486′)/ 24 = 55′ 1/4, agrees with the mean motion forming one *pada*. (Incidentally, this justifies our amendment of *visayarasonā* into *viṣayaraseśāḥ*. There are other justifications also, as we shall show later). Further, the first sector being a continuity of the third, the rate during the first *pada* in the first sector must follow next to the rate during the 16th *pada* of the third sector. Since 1486′/24 is taken as the motion of the first *pada*, the motion of the 16th is (1486-30)/24 = 1456′/24. This must be the commencement of the third sector, and this is what is given. We can also see that the fastest rate, (at perigee), is 1486′/24 = 62′, and the slowest, 1165′/24 = 48′ 1/2, (at apogee), giving the mean value 55 1/4, of the *pada*, already found. But the rate for the 196th *pada*, ending which there is the apogee, is, (1486 – 195 × 2)′/24 = 1096′/24. But the minimum motion falling at apogee is given as 1165′/24. This hiatus must also be due to the fact that the 2′/24 increase in the rate per *pada* is only approximate, and the actual is a little less than 2′/24. But the formulae are so given that the total of the first sector is (1456 – 180) 180′/24 = 5^r 9° 30′, as given. The total of the second sector is, (1165 + 195) 195′/24 = 6^r 4° 10′. The total of the third sector is, (1486 – 16) 16′/24 = 16° 20′. These add up to 12 *rāśis*, exactly, as they should. Incidentally, this justifies my emendation of *gunāṃśāḥ* into *yugaṃśāḥ*, *pāñcaguṇite* into *padaguṇite*, and giving the meaning of *tryaṣṭaka* as 3 × 8 = 24. The justification for correcting *vidhṛtayaḥ* into *khadhṛtayaḥ* to get 180, and *rasonā* into *raseśā* to get 1165, are also reinforced by this perfect agreement found here.

TS and NP also give *khadhṛtayaḥ:, seeing the reason for that. TS emend rasonāḥ* into *rasenā* (= 1265), which will give the total 6^r 17° 43′, far from the correct 6^r 4° 10′. The text itself gives 6^r 3° 10′, one degree off. TS give 6 *rāśis* exactly, not knowing the peculiarity of this *Siddhānta*. Using *cakrārdhe* thus, they are left with *guṇāśaḥ daśa ca kulāḥ*. This they interpret as 13° (wrongly, for it can mean only 30 or 103). Emending *daśa ca kalāḥ* into *paraśakale,* they say that this 13° is the total motion of the third sector. They do not realise that the 16 *padas* of the third sector is near perigee, and the total motion must be greater than the mean motion, 14° 44′. Not knowing the nature of the method here, they think that the total of the third sector also should be given. It has no use, and Varāhamihira has not given it.

About *pāncaguṇite tryaṣṭakabhājite*, I have emended *pānca* into *pada*, to delete the one *mātrā* in excess, and to give the agreement already seen. *tryaṣṭaka* is 24, as already said. TS retain the *pañca,* but emend *tryaṣṭaka* into *aṣṭaka*, making it 5/8, leading nowhere.

As for NP, they generally follow TS's emendations. But, for the divisor 8 they suggest the alternative 83 (*tryaṣṭaka*). Unlike TS, they realise that the three sectors must add upto 12 *rāśis* and make their own emendation of the last part of verse 11, as *dviguṇāṃśā daśa sadalā,* interpreting it as 20° 30′. NP have given the gist of verse correctly, but making a lot of unnecessary emendations. They have wondered in Part II, why such small units, as *padas*, have been taken. This is because, they

seem to think, that the three sectors are each taken wholly to get intermediate values by interpolation. An examination of the total of each sector would show how wrong it would be. The true eq. cent. corrected Jupiter is given for the end of any *pada* we want. We are expected to use these to get the true motion through any segmentation of the total *padas*, for correct interpolation, and the ends of the segments may fall anywhere, from *pada 0* to *pada* 390. Therefore the small *pada* segments are used. I shall work out an example at the end to make everything clear.

I shall explain the rationale of the instruction in verse 8, of adding or subtracting the difference. The eq. cent-corrected Jupiter is subtracted from the Sun to get the anomaly of conjunction. So, a positive eq. cent. means less anomaly of conjunction. The days left over represent the anomaly of conj. with the 399 days of the synodic period, corresponding to 360° of anomaly. So the day is taken as *roughly equal* to the degree of anomaly, and th e difference in degree subtracted. Vice versa for the eq. cent. corrected Jupiter, it being less then the mean. Varāhamihira is too astute to confuse day and degree, as NP think. (In verses 64-81 too, there is no confusion in the author's mind, as NP seem to think. There he has deliberately chosen the time taken by the Sun to move one degree as the unit of time, and call it 'day', for convenience. This is patent on the face of the synodic periods given, though TS have not even seen it, and are perplexed. We have reason to think that verses 64-81 are by somebody else).

दिन(षष्ट्यांशान्) द्वादश 'खकृतैर्वे(दान्)' 'कृताश्विभिर्द्वौ' च |
सप्ताष्टकेन वक्री षड्[भागान्] षष्टितः षट् च || १२ ||
अनुव(क्रो)ऽशीत्यार्का(न्' द्व्यू)नार्ध(श)तेन नव ततोऽस्तमितः |
स्थित्वा सैकं मासं स्फुटोद(योऽष्टोत्तरैरङ्गैः) || १३ ||
|| बृहस्पति : ||

12. By 60 days, (Jupiter moves) 12°, by 40 days 4° and by 24 days 2°. Becoming retrograde, by 56 days he moves 6° (i.e. −6°) and by 60 days, 6° (i.e. −6°).

13. Following after retrograde, he moves 12° in 80 days, and 9° in 48 days. Then setting, staying so for a month plus one day, he clearly rises moving 6° 8′. Ends Jupiter.

The Scheme given

Days	Rising east	60	40	24	56	60	80	48	Setting wast	31	Rising east	= 399
Degrees		12°	4°	2°	− 6°	− 6°	12°	9°		6°8′		= 33°8′

12a. A.B. षष्ट्यंशा; C.D. षष्ट्यांशा
b. A.B.C.D. वेदाः
c. B. सप्ताष्टाकेन
d. A.B. षड्वर्गाः. B. षष्टि षद्
B. combines with the next verse.
षष्ट्यनुवक्री

13b. A.B. वक्रीशीत्यर्का (B. र्का) द्
b. A.B. द्विनार्धमतेन; C. ध्यूनार्धशतेन; D. दिनार्धशतेन
D. नव [च] ततो
c. B. स्छित्वा. D. स्थित्वा [श्व] मेकमासं
d. A.B. स्फुटोदयाष्टान्तरं (B. तारं)
मारां (B. मासमी); C. स्फुटोदयोऽस्योत्तरे मासे;
D. स्फुटोदयो स्त्वन्त्ये मासस्य

These values agree well with actualities, considering that whole days and whole degrees are given, excepting the last 6° 8′, given to complete the value for the synodic cycle. 6° 12′ would be better at that region and for the whole number, 399 days. 56 days for – 6°, and 60 days for the same – 6° must be explained by the intention to give whole degrees and segmentation.

Vargāḥ is an obvious mistake for *bhāgān*, and so corrected. TS have interpreted *saptāṣṭakena* to mean 15, which such an expression never means. It can mean either 56 or 87. They understand another 60 days by the word *ca* used. All this, to make up the wrong scheme used by them, based on the mistaken idea that the statement of motions here begins with conjunction and ends with the rising in the east after the next conjunction. The following is their scheme:

Days Conjunction	60	40	24	15	60	60	80	45	Setting west	30	Rising east	= 414
Degrees	12°	4°	2°	0°	– 6°	– 6°	12°	9°		(15°)		= 42°

ddīnārdhamatena is emended by TS into *dhyūnārdhaśatena* but how can this word mean their 45? As for the last part, *sthitvā saikam māsaṃ*, they have taken it to mean 30 days instead of the correct 31 days. Let that be. They have not given any motion for it in their interpretation. It cannot be left to be guessed and completed by an ordinary computer. They, who can be expected to know, have guessed, quite wrongly, 15° motion for 30 days, not realising that it can be only 6° and a few minutes more. For the 414 days from conj. to the rising after the conjunction, the total can only be about, 33° 9′ + 3° = 36° 9′, and not the 42° given by them.

As for NP, they have emended *ddīnārdhamatena* into *dinārdhaśatena* to mean 50 days. Since they take 30 days for the setting i.e. one day less, they make the total of days, 400. They give 7° motion for the 30 days (which they make even 29 days in the last part). They have changed the wording to some ununderstandable form here, *dyavantye māsasya*. Further, the 7° is far too much for 30 days. But there is no 7° in the text. They have corrected the text *saikam* into *śvam*, thinking that *aśvam* in *bhūtasaṇkhyā* means 7°.

Incidentally, one other matter may be considered here, viz., the degrees of heliacal rising, for Jupiter. During the set-period of 31 days, the sun moves about 30½ degrees, and Jupiter, about 6° 8′, and the relative motion is 30½° – 6° 8′ = about 24°, from setting to rising. This gives about 12°, for the heliacal rising of Jupiter, which is fairly accurate, especially for very high latitudes. (Classical Hindu astronomy gives 11°). Verse XVIII. 58 gives the *Vaśiṣṭha-Pauliśa's* degrees of heliacal rising as 12°, 14°, 12°, 15°, 8°, 15° from Moon onwards, by *candrādinām dvādaśamanuravitithyaṣṭatithisaṃkhyaiḥ:*. 15° for Jupiter given here is too much, and 14° for Mars is too low. (Classical Hindu astronomy gives 17° for Mars). So, the scribe seems to have made a small change in the order, and the correct order is "*candrādīnām dvādaśatithimanuravyaṣṭatithisaṅkhyaiḥ:*", 12°, 15°, 14°, 12°, 8°, 15°, with only one change of place.

Example: Find the True Jupiter at 2415 days from epoch.

(i) The beginning of the first cycle after rising next to the epoch is 34-34 days later.
The days after this, required to find the number of cycles gone = 2415 – 34-34 = 2380-26.
Dividing by 399, cycles gone = 2380 – 26/399 = 5, with 385-26 remainder.
Adding 5 × 1/9 days, (= 0-33), we have 385-59 days left over after 5 cycles gone.

(ii) The *padas* at 5 cycles gone = 18 + 5 × 36 = 198.
Mean Jupiter = 198 *padas* = 198 × 360°/391 = 6^r 2° 18′.
True Jupiter:-
For the 198 *padas*, 180 *padas* forming the first sector has gone and 18 *padas* are left over in the second sector.

$\therefore$ True Jupiter $= 5^r 9^\circ 30' + (1165 + 18)\, 18'/24 = 5^r 9^\circ 30' + 14^\circ 47' = 5^r 24^\circ 17'$.
Eq. cent. $=$ True $-$ Mean $= 5^r 4^\circ 17' - 6^r 2^\circ 18' = -8^\circ 1'$.

(iii) The *padas* at 399 days in the cycle, i.e., the beginning of 6 cycles gone $= 198 + 36 = 234 = 180 + 54$.
Mean Jupiter $= 234 \times 360 \div 391 = 7^r 5^\circ 27'$.
True Jupiter $= 5^r 9^\circ 30' + (1165 + 54)\, 54'/24 = 6^r 25^\circ 13'$
True $-$ mean $=$ Eq. cent. $= 10^\circ 14'$.
Eq. cent. at 0 day of 6th cycle $= -8^\circ 1'$
Eq. cent. at 399 days of 6th cycle $= -\ 8^\circ 1'$
Eq. cent. at remaining days (385-59) =
$= (385\text{-}59) \times -2^\circ 13' \div 399 + -8^\circ 1' = -10^\circ 10'$.

(iv) *True* Jup. is less than Mean Jup. by $10^\circ 10'$. $\therefore$ days of Anomaly of Conj. $= 385\text{-}59 + 10\text{-}10 = 396\text{-}9$.

(v) True an. of conj. =

for 60 days	$+ 12^\circ$	
for 40 days	$+ 4^\circ$	
for 24 days	$+ 2^\circ$	
for 56 days	$- 6^\circ$	
for 60 days	$- 6^\circ$	
for 80 days	$+ 12^\circ$	
for 48 days	$+ 9^\circ$	
Total 368 days	$+ 27^\circ$	
for 28-9 days	$5^\circ 32'$	$\frac{28\text{-}9}{31} \times 6^\circ 8' = 5^\circ 32'$
396-9	$32^\circ 32'$	

(vi) True Jup. = Mean Jup. at 0 day of An. of conj. + eq. cent. + true ano. of conj.
$= 6^r 2^\circ 18' - 10^\circ 10' + 32^\circ 32' = 6^r 24^\circ 40'$.

Note 1: The need for interpolating the eq. cent. to the remaining days in the cycle can be seen by working for 399 days of the 6th cycle and 0 day of the 7th cycle and comparing. They must be the same.

Note 2: The eq. cent. is computed for 0 day of each cycle, i.e., for intervals of 36 *padas* $= 33^\circ 9'$. Interpolation using these, as we have done, can be only rough. To get better interpolations, we can divide the 36 *padas* into desired segments, find the eq. cent. of each, and use. We can form an ephemeride, giving the values at the ends of the day segments given, 60, 40, 24, etc. and use for interpolation. All these logically follow from the instructions, though not specifically stated.

[शनिचारः]

अध्यर्धशतं (स)त्र्यंशमपनयेत् सूर्यजस्य दिवसेभ्यः ।
'वसुमुनिगुणो' (द्धृ)तेभ्यः स्थि(ता) दिनाद्या(स्स)मभ्युदयात् ॥ १४ ॥

जह्या(दु)दयदशांशं द्युभ्यो नवसंगुणा(न् भ)जेदुदया(न्) ।
'षड्विषययमैः' शेषं पदैर्युतं त(न्न)वाशीत्या ॥ १५ ॥

Motion of Saturn

As already has been said, the treatment of Saturn is similar to that of Jupiter. So there will be little need for fresh explanations.

> 14. Regarding Saturn, 150-20 days are to be subtracted from the days from epoch. These being divided by 378, the remainder are the days from the rising gone, the quotient being the number of risings gone.
>
> 15. One tenth of the risings, (i.e., the quotient), in days, is to be subtracted from the remainder. The number of risings got is to be multiplied by 9, and divided out by 256. The remainder *plus* 89 *padas* form (the *padas* required for using in the computation). (The idea is that 89 is to be added to (quotient × 9), and then divided by 256, to find the *padas* for use).

In (15), I have emended *saṅguṇād* and *rudayāt* into *saṅguṇān* and *rudayān* to agree with *bhajet* requiring accusatives; so also NP. But TS have kept them. In NP's emendation *dinādyāptam*, *āptam* does not agree with the word *sthitā* and, the meaning also is redundant. Both TS and NP have emended *padaiḥ* into *pade*, thinking that *navāśītiḥ* is degrees. Even this they doubt, as seen in the translation, because as mentioned by them in Part II, page 124, it had led to disagreement. *Padaiḥ*, as it is, clearly, says that the 89 is *padas*. So is the 18 of Jupiter and the 85 of Mars.

We understand from the instructions that the synodic revolution of Saturn takes 378′/10 days, that in one synodic revolution Saturn moves 9 *padas*, that 256 *padas* make nine sidereal revolutions of Saturn, that there are 256 + 9 = 265 sidereal revolutions of the sun in 256 synodic periods of Saturn, and that at 150-20 days from epoch, Saturn's mean longitude is 89 *padas*. (NP give in their translation, "89°?", as mentioned already. Therefore, one sidereal revolution of Saturn takes 378′/10 × 256 ÷ 9 = 10754.84 days. One sid. revolution of the sun = 378′/10 × 256 ÷ 265 = 365-15-32.

Again, the Sun's sid. period got is *Pauliśa's*.

One *pada* = 360°/256 = 84′ 22″.5. The motion in one synodic revolution = 9 × 84′ 22″.5 = 12° 39′ 22″.5.

Mean Saturn at 150-20 days after epoch = 89 ×84′ 22″.5 = 125° 9′.4.

'षड्रूपवेदपक्षाद्' वृद्धिस्त्रिंशत्पदानि सौरस्य |
'नवरूपविषययमला(द्)' ह्रासः 'स्वरभास्कर'पदा(न्तः) || १६ ||

प्रचयः 'स्वराग्निखयमान्' नवनव(ति)स्त्रिघनभागलिप्तानाम् |
क्षयवृ(द्धी) द्विगुणपदैरेकगुणघ्नः श(नेरु)दयः || १७ ||

षोडश वृषभस्यांशा नवलिप्तावर्जिताः प्रथमख(ण्डे) |
'विषया'स्त्रिघ(ना)स्त्रिंश(त्) चतुर्युता मध्यमे खण्डे || १८ ||

14a. A. शत्र्यं; om. the two letters.
b. B. णमपानये सूर्य
c. A.B. गुणोघृतेभ्यः
d. A.B.D. स्थितं. A.B. दिनाद्यास्स; D. दिनाद्याप्त

15a. A.B. जह्याद्युदय. B. दष्टांश
b. B. नवसं°. A.B.C. भजेदुदयात्
d. C.D. पदं युतं. A. तन्तवाशीत्या; B. मत्तवाशीत्या

16. Regarding Saturn, there is an increase (of the rate of motion) for thirty *padas*, from 2416. Then, there is a decrease for 127 *padas* from 2519.

17. Next there is an increase for 99 *padas* from 2037. The amount of decrease and increase are by the padas multiplied by 2. The divisor of the total minutes is 27, its multiplier being one.

18. The total of the first sector is $1^r\ 15°\ 51'$ and the total of the middle sector is $5^r\ 27°\ 34'$.

Note: The multiplication by one is unnecessary, but given to clear the doubt that may arise by the instruction to multiply the *padas* by two for subtraction and additions coming before.

The meaning is clear, and no material change has been needed. I shall give what is given in the form of formulae:

The total motion upto any *pada* in the first sector, viz., (1-30) = (2416 + 2 × *padas*) *padas* ÷ 27, in minutes.

That in the second sector, viz., (31-157) = (2519 − 2 × *padas*) *padas* ÷ 27, in minutes.

That in the third sector, viz., (158-256) = (2037 + 2 × *padas*) *padas* ÷ 27, in minutes.

The total of the whole of first sector given. $1^r\ 15°\ 51'$ can be verified thus:
$(2416 + 2 \times 30)\ 30 \div 27 = 2751' = 1^r\ 15°\ 51'$ given.
The total of the whole second sector = $(2519 - 2 \times 127)\ 127 \div 27 = 10654' = 5^r\ 27°\ 34'$, given.

Being unnecessary, the total of the third sector is not given. But we can calculate it and use it to see if all those add up to 12 rāśis, as necessary, and this will verify every instruction given.

The total of the third sector = $(2037 + 2 \times 99) \times 99' \div 27 = 8195' = 4^r\ 16°\ 35'$. Now, $1^r\ 15°\ 51' + 5^r\ 27°\ 34' + 4^r\ 16°\ 35' = 12^r$.

Examining the constants, we find that the maximum motion per *pada* is $2519' \div 27 = 93'.3$. The minimum rate is $2037' \div 27 = 75'.4$. The mean rate is = 84′ .35 as already found, as the mean motion equal to the *pada*. Differentiating as before, the increase or decrease in the rate is 4′/27. Actually it is slightly less than this, the multiplier being slightly less than 2, given. $(2037 + 4 \times 98) = 2416$ shows this. The perigee falls at end of 30 *padas*, i.e., $1^r\ 14°$, and the apogee, 127 *padas* later, at $7^r\ 13°$.

The instruction how to use the result of these verses has not been given, because it is the same as that given in verse 8 for Jupiter. Indeed, the un-emended reading *saure* there means, "with reference to Saturn".

16a. B. षड्भूप. A.D. पक्षा
c. A.C.D. यमला; B यमलो
d. A.B.C.D. पदाख्यः
17a. A.B.C.D. यमा
b. A. नवनवतस्तिघन; B. नवनवतस्त्रिघन
c. A. वृद्धि; C.D. वृद्धिः
c-d. C.D. द्विगुणहतश्चैकगुणघ्नः
d. A.B. शनैरुदयः
18a. B. वृषभांशा
b. A. खण्डाः; B. खण्डा
c. A.B.C.D. त्रिघनः. A.B. त्रिंशः

As in the case of Jupiter, here too TS and NP have not understood what exactly is given in these verses, how it is got by applying the three formulae, how the eq. cent. is got, and why the instruction to apply this to the days remaining is given, in the manner said.

So, their emendations of the readings, done without knowing the subject matter, need not be taken seriously. TS have emended the correct *dviguṇapadaiḥ:* into *dviguṇahṛtaḥ*, meaning "divided by 32", applied to the risings and not to the number got in the formulae. NP have kept the reading, but given the translation as, "There is a subtraction or addition of 12 degrees and minutes, (i.e., 12° 12′). Multiply by 31 and divide (the product) by 32 (or by 32 *padas*). (The result is) Saturn's rising." Where is 12° 12′ mentioned? They take the 32, not as a number, but as a segment of longitude equal to 32 *padas*, i.e., 45°. Again, how can this give the risings? And the risings have already been given in verse 14. All these show that they do not understand what is said.

षड्(कृत्या त्रीनं)शान् (मुनि)भिर्लिप्ता '(श्रेषु) गुणास्सप्त' |
षोडशभिश्चाशी(तिं) कृतोनषष्ट्या '(वेदयम)' पक्षान् || १९ ||
वक्री वि'भूतषष्ट्या' (त्री)नंशान् षष्टितः 'कृतान्' सौरः |
अनुगो'ऽर्कश(ते'ना)ष्टौ षट्कृत्या चास्त(गो) 'दहनम्' || २० ||
|| शनैश्चरः ||

19. Saturn (moves) 3° in 36 days, 35′ in 7 days, 80′ in 16 days, and 224′ in 56 days.

20. Then becoming retrograde, he moves 3° in 55 days, and 4° in 60 days. Then, following up direct, he moves 8° in 112 days, and setting, he moves 3° in 36 days in the set period, (i.e., rises in the east after that). *Ends Saturn.*

This is the scheme given

Days Rising east	36	7	16	56	Retrograde	55	60	Direct	112	Setting west	36	Rising east	= 378
Degrees	3°	35′	1°20′	3°44′		– 3°	– 4°		8°		3°		= 12°39′

I shall now discuss the values given, justifying the three emendations. I have made. The corrupt *saḍhratāstrīṇaṃśān* has to be emended as 3° for 36 days, considering the position, and the fact that it must practically be equal to the rate between setting and rising, 3° for 36 days. The days must add upto 378 days from rising to rising, also as from conjunction to conjunction. All the numbers for

19a. A.B. षट्हताः; C. खण्डान्त्ये. D. परिहोनाः
b. A.B. स्त्रीणांशान्; C. सिंहांशा. D. स्त्रीखांशा
c. A.B.D. लिप्ताश्चतुर्गुणाः
c. A.B. श्चाशीति; C. श्चांशाग्रीन्
d. A.B.C.D. षष्ट्या द्विगुणपक्षान् (A. पक्षात्. B1.2. पक्षा. B. श written after पक्षा)

20a. B. विभुत
a-b. C. षष्टाष्टरसैस्त्रीन् षष्टितः
A. त्रिनंशान्; B. त्रिनशान्; A1. कृतात् सौरः; B1.3. कृत्यसौरः
c. A. शतैर्नाष्टौ; B1. शतैर्माष्टो (B2. र्माष्टों); D. शतेनाष्टौ
d. A1.2. गे दहनं || B1.2. षड्भत्या वास्तये दहनं ||

days are clear. Therefore, the days for the second segment must be 7. So I have emended *manu* into *muni*. The motion given there, 28′, gives the rate 2′, too absurd for that position, if the original 14 days are accepted, and it cannot be that the *Siddhānta* does not know the absurdity. Even for the emended 7 days, it is too low, being only 4′ rate, while the rate on both sides is 5′, and also consistent with facts. Therefore, *ścaturguṇā* is emended into *ścesuguṇā*. Now, these three segments can be combined into 4° 55′ for 59 days, without affecting the result. I do not know why the *Siddhānta* has broken it into such bits.

Next, the total for the 378 days must be the mean motion for the period, i.e., 9 *padas*, equal to 12° 39′.4, roughly taken by the *Siddhānta* as 12° 39′. Therefore the motion for the fourth segment, 56 days, must be 224′. So I have emended *dviguṇa* into *vedayama*.

In the case of Saturn, too, as in the case of Jupiter, TS and NP have thought that the unnecessary total motion for the third sector has been given. Finding no wording answering to that, they have changed drastically the first half of verse 19, and obliterated the first two segments of days and motion. They have emended the half verse into *khaṇḍentye siṃhāśāmunayo liptāścaturguṇāssaptā*, as if they are writing their own book. This means, in the last sector the total is 4ʳ 7° 28′. But even this does not help to get 12 *rāśis*, the total coming to only 11ʳ 20° 53′.

With the other half and the next verse, they make up the whole scheme as:-

days	16	56	55	68	60	105	36	= 396
motion	+ 3°	+232′	+4°	−3°	−4°	+8°	+3°	= 15°

changing *aśīti* into *aṃśāgnīn*; not giving any word for the motion of 4° in 55 days, but simply putting the motion there; *trīnaṃśān* into *aṣṭarasaistrīn*, newly introducing 68 days, and giving it the retrograde motion −3°; and *arkaśatena* into *arthaśatena* to mean 105 days. As in the case of Jupiter, they trace the motion from conjunction to the rising after the next conjunction, taking 396 days. But the total motions must then be, 12° 39′ + 1° 30′ = 14° 9′ and not 15° given. They must know that 3° for 16 days, giving the rate 11¼′ per day is very much wrong, when the rate is only 5′ for the nearer segment got from the motion 3° for 36 days.

As for NP, they emended the first half of verse 19, as *parihīnāḥ strīkhāṃśā manubhirliptāścesuguṇās-sapta* meaning "Zero degree of Virgo diminished by 14°, plus 35′ ″, i.e., 4ʳ 16° 35′. They are here better than TS because they have seen that the aim should be to get the total of 12 *rāśis* for the three sectors combined. They have also kept closer to the lettering of the text, though the manner in which they have got their total for the third sector is far-fetched. After this, they follow the text without changing it. Only at the end they interpret that the motion of 3° for 36 days comes before the setting, and leave the period set without any days or motion given. Thus, their scheme is:

days	Rising east	16	Retro-	56	55	60	Direct	112	36	Setting	? Rising	Total 378
motion		80	grade	232′	−3°	−4°		8°	3°	west	? east	Total 12° 39′

To make up the totals, a motion of 3° 27′ for 43 days has to be given. But it must be at least 3° 35′. For the 43 days of the set period, the sun's motion is 42° 20′. Therefore, the degrees of Saturn for heliacal rising comes to (42° 20′ − 3° 27′) ÷ 2 = 19° 26′. This is far greater than the 15° given in verse 58, and also in all *Siddhāntas*. Further, the opposition must occur at the middle of the period from rising to setting and also the middle of the retrograde period. The one falls 160 days after rising, and the other 130 days after, as great as 30 days off. I am sure NP have noted all these discrepancies, but have given them as they understood the wording, just to mark time.

I shall now give an example, to make the method clear.

Example: Find true Saturn at 5000 days gone from epoch.

i. Days 5000
To be subtracted 150-20

Divided by 378 | 4849-40 (12 = full cycles gone)
313-40 = (Remaining days)

Days to be deducted $\frac{10}{12}$: 1-12

312-28 (corrected remainder)

ii. Padas at 0 day of the 13th cycle: $\frac{89 + 12 \times 9}{256} = 197$ remainder

Mean longitude = 197 padas = $9^r\,7°\,2'$
197 = 30 + 127 + 40 (in the third sector)
Eq. cent. corrected mean longitude:-
$= 1^r\,15°\,51' + 5^r\,27°\,34' + (2037 + 2 \times 40)\,40' \div 27$
$= 1^r\,15°\,51' + 5^r\,27°\,34' + 1^r\,22°\,16' = 9^r\,5°\,41'$
Eq. cent. $= 9^r\,5°\,41' - 9^r\,7°\,2' = -1°\,21'$

iii. *Padas* at 378 days gone in the cycle = 197 + 9 = 206

Mean longitude = 206 *padas* = $9^r\,19°\,41'$

206 *padas* = 30 + 127 + 49 (in the third sector)
Eq. cent. corrected mean longitude $= 1^r\,15°\,51' + 5^r\,27°\,34' + (2037 + 2 \times 47)\,47'/27 = 9^r\,18°\,0'$
Eq. cent. $= 9^r\,18°\,0' - 9^r\,19°\,41' = -1°\,41'$
Interpolated for days 312-28, the eq. cent $= -1°\,21' - 0°\,17' = -1°\,38'$.

iv. Correcting the remaining days 312-28 by this, 312-28 + 1-38 = 314-6 days, to be used to find anomaly of conjunction.

v. 36 days	+3°		
7 ...	+ 0° 35′	Mean Sat. at 0 day	$9^r\,7°\,2'$
16 ...	+ 1° 20′	Eq. cent	− 1° 38′
56 ...	+ 3° 42′	An. of conj.	+ 7° 40′
55 ...	− 3°		
60 ...	− 4°	True Saturn =	$9^r\,13°\,4'$
Remaining 84-6	+ 6° 1′		
314-6	+ 7° 40′	As per Ephemeris:	$9^r\,11°.7$ (*sāyana*)

Mars

As indicated earlier, Mars, like Mercury, needed elaborate treatment owing to certain peculiarities about it, and so had been reserved by VM to the end of *PS*. The synodic period of

Mars, on which the equation of conjunction depends, is 780 days, during which there are more than two revolutions of the Sun, and one revolution of Mars, so that one full anomalistic period of Mars is contained within this period. This, with the large equation of the centre, and the large equation of conjunction causes large variations in its motion from sign to sign, and even in the same sign, according to the different types of motion governed by the anomaly of conjunction, like, fast, slow, retrograde etc. Hence is the need for detailed treatment.

Further we have reason to think that the various motions given are all empirical, based on long observation, synodic period after synodic period. The separation into the equation of the centre, and the equation of conjunction is yet to come, it seems, unlike the cases of Jupiter and Saturn, where it is easy, and done. This would explain discrepancies found in the values given.

Regarding the constants given, some can be verified by mutual comparison, and corrected where necessary, when there is a doubt about the reading itself. But some, like the epoch constants, which are peculiar to the *Siddhānta* itself, cannot be so verified and corrected when there is a doubt. Only in such cases, where we can argue that no *Siddhānta* is likely to give such wrong values, and when these values are so far from the real, that we can make some plausible corrections.

TS and NP have not understood the nature of the motion of Mars, ju... as they have not understood Jupiter and Saturn. While TS have not even attempted translating some verses, wrongly interpreting those attempted, NP have attempted translating all, but many wrongly. I shall point out these after my own translation and discussion of the verses, step by step.

[कुजचारः]

द्युगणे 'षट्(पञ्च)यमान्' विहाय पञ्चाष्टकं च नाडीनाम् |
'गगनाष्टमुनिभि'रुदया लभ्यन्ते प्राङ् महीजस्य || २१ ||

उदयगुणिता विनाड्यः 'स्वरतिथयोऽ(ब्ध्य)'न्विता दिनक्षेपः |
'धृतिगुणि(तांस्त्र्यग्नीन्दु)' भिरुदया(न् ह)त्वा स्थितो (तस्मिन्) || २२ ||

पञ्चाशीतिं कृत्वा प्रतिराश्य मध्यमः क्रमशः |
राशिप्रमाणतोऽ(स्य) स्फुट(तश्च)रक्रमं कुर्यात् || २३ ||

स्फुटमध्यम(विश्लेषां)शान् क्षिपेत् मध्यमे [ऽधिके] द्युभ्यः |
मध्यमहानौ जह्यात् गतितोऽथ चारा(न)भिधास्ये || २४ ||

Motion of Mars

21. Subtracting 256-40-0 days from the days from Epoch, and dividing by 780, the synodic risings of Mars in the East are got.

22-23. (157 *plus* 4) *vināḍis*, multiplied by the risings got, are to be added to the remaining days. Multiply the risings got by 18, and adding 85, divide by 133. The remainder, converted into *rāśis* is Mars at rising. According to the whole or portions of *rāśis*, the true motions are to be taken one after another, and pieced together.

24. The difference between the mean and true degrees should be added (to the remaining days got in 21), if the mean is greater. If the mean is less, the difference should be subtracted from the remaining days. This done, I shall give the true motions, according to each type of motion:

We learn from the verses the following:

1. 256-40-0 days from Epoch, Mars rises in the East, after which the counting of risings begin.
2. One synodic revolution takes 780 days – 161 *viñaḍis*, (i.e. 779-57-19 days). The addition of *viñaḍis* multiplied by revolutions, is for taking the synodic period as 780 days approximately.
3. For this period of 779-57-19 days, we get 1 + 18/133 sidereal revolution of Mars, and 2 + 18/133 sidereal revolutions of the Sun. So, in one synodic period, Mars moves 408° 43′.3
4. In 133 syn. periods = 1,03,734-3-7 days, there are 151 sid. rev. of Mars, and 284 sid. rev. of the Sun. From this, the Sun's sid. period got is 365-15-38 days and Mars's 686-58-50 days. The Sun's period is 38 *viñaḍis* more than that given for it by the *Vāsiṣṭha*, and near the 365-15-30 of the *Pauliśa*. Therefore, like the Moon, Venus, Jupiter and Saturn, Mars also is common to *Pauliśa*.
5. At the first rising when calculation commences, mean Mars = 85/133 rev. = 7^r 20° 4′.5
6. The addition or subtraction of the difference from the remaining days has been already explained with reference to Jupiter and Saturn. But, here, no method is given to find the equation of the centre. Now the true motion is affected by both the eq. of the centre and eq. of conjunction. The segments of motion given in verses 25-26, below, are as affected by the eq. of conjunction alone. By making the days given for true motion in verses 27-35 conform to the segments, we can get the degrees, and through that the days affected by the eq. centre alone. This can be of use only for the remainder of days. But the eq. of centre at the beginning of each cycle is necessary. It has not been given by any rule. Since its period is about 687 days and it has its own rise and fall of about 11° from perigee to apogee and back, it cannot be associated with the synodic period of 780 days. So this is an omission.

I have corrected the corrupt *tāstrayāmrīdubhiḥ* into *tāms tryagnīndubhiḥ* to mean 133. This is necessary for agreement with the actuals, and the effect of my emendation is seen in my discussion (3) above. TS have made it *bāṇendubhiḥ*. How can *bāṇa*, with such different lettering, come in here? Further, this will give 18/15 rev. = 432° as the mean motion of Mars in one syn. period, about 23° wrong per period. They have made *pañcāśīti kṛtvā* into *pañcāṃśonam kṛtvā* and thus shut out the position constant of Mars on the first day where reckoning begins, viz. the point of time 256-40-0 days from epoch. (It will be remembered that in the cases of Moon, Venus, Jupiter and Saturn also, they have made this mistake). By this emendation they reduce the motion by 86° 24′, and make the

21a. C.D. द्युगणात्
A.B. षट्कं व यमान् (B3. पट्कं). D. षट्कैकयमान्
b. B. नाडित्वं
d. B. प्राक्
22b. A. योब्धान्विता; B. सोब्दान्विताः
c. A.B. गुणितास्त्रयम्री (B. त्री) दुभि; C.D. °गुणितान् बाणेन्दुभि
d. A2. हत्वा; A.B. स्थितो तो समाः;
C.D. स्थितोऽतोऽस्मात्
23a. A.B. पञ्चशीति; C.D. [पञ्चांशोनं]
b. C.D. प्रतिराशिं;
B. मध्यतः. A.B. क्रमश
c. A.B. प्रमाणतो स
d. A.B.C. स्फुटता चार°; D. स्फुटिता चार°
B. क्रकुर्यात्; D. क्रम [ात्] कुर्यात्
24a. A.B. विक्षेपां
b. A. °शन् क्षिपेत्; B.C.D. शकान् क्षिपेत्
c. A.B.C.D. मध्यमे द्युभ्यः
d. A. गतितोथाचारमभि°; B. गतितोष्याचारमभि°;
C. गतितोऽथो चारमभि; D. गतितोऽप्याचारमभि°

mean motion of Mars 345° 36′ per syn. period of 780 days! They have also wrongly emended *pratirāśya* to *pratirāśyam*.

As for NP, they have made the correct emendation *tryagnīndubhiḥ*, giving correctly 151 revolutions of mean Mars in 133 syn. periods, and identified it with that given by the Babylonian astronomy of the Selucid period.

But NP have not seen that *pañcāśītim* meaning 85, is correct as it is, and give the constant 7^r 20° 4′.5 at 256-40-0 days from epoch (see item 5 of discussion). They think it is the constant in degrees, though no word meaning degrees is found here. (This kind of mistake they have made in the case of Jupiter and Saturn also, as we have shown). But 85° would not do, so they have substituted *satrirāśim* for *pratirāśya* and made it 175°. But even this would not do, and therefore they have changed the days from Epoch itself into 216-40-0, by emending *ṣaṭkam va yamān* into *ṣaṭkaikayamān*. But this has led to other troubles, leading to their remark, "For Mars this would mean a longitude of 175° (instead of 194° derived on the basis of a_0 in table 32). This longitude would correspond to September 27, and a solar position at 186°, hence to an elongation of 11°" (p.124, Part II). 11° for the first visibility of Mars is given by nobody. It is in the range of 14° to 17°.

प्रागुदये षट्(चत्वार्येक)मष्टादश(ग)स्ततो वक्रम् |
अध्यर्धं च शतं शीघ्रां[स्ततोऽस्तमितो द्यूनां षष्ट्या] || २५ ||
समतीत्य दशत्रियु(तं) निरंशगतो(ऽतस्त्रिंशतं) व्यतीत्य कुजः |
उदयमुपयाति वक्ष्ये गतिचारदि(न)क्रमे चातः || २६ ||

25-26. After rising in the East, Mars moves 146° (in quick motion) and then 18° each of (slow motion), retrograde and "follow up after" retrograde (*anuvakra*), and after that 150° of quick (*śīghra*) motion. Then setting, it reaches conjunction (*niraṃśagataḥ*) in 60 days moving 13 plus 30 (= 43) degrees. Then it rises, (moving the same degree in the same number of days). Beginning from here, I shall mention the series of motions with their days.

The scheme is

		Rises East	
Moves 146°	I	type of motion	(*śīghragati*)
18°	II		(*Mandagati*)
−18°	III & IV		(*Vakaragati*)
			(*Ativakragati*)
18°	V		(*Anuvakragati*)
150°	VI		(*Śīghragati*)
		Sets in the West	
43°	VII in 60 days		(*Atiśīghragati*)
		Conjunction	
43°	VIII in 60 days		(")
		Rises in the East	
Total 400°			

The numbers I have given in the scheme are practically what are found in the text, without emendation excepting three. In verse 25, I have emended *captasteka* into *catvāryeka* to get 146° the most plausible value. NP have made it *ṣaṣṭāṣṭaika* to get 186° which is too large. See discussion below, 150° is given by *adhyardhaṃ ca śatam* where *tataḥ* is emended into *śatam*. This is necessary to make up the total 410° motion in 780 days. Secondly, 43° motion for 60 days given from setting to conjunction is required to agree with the 17° usually given for heliacal rising. This is made up by emending *viṃśatam* into *triṃśatam* with the 13° given by *daśatriyutam* added. I shall now show that the motion of Mars is near 43° in 60 days, in the region of the conjunction. For its distance, nearly 1.53 that of the Sun, given by modern astronomy and also as computed from Hindu astronomy, the equation of conjunction at this region is 11′ per day, (as can be verified) which, *plus* the daily mean motion of 31′.4 gives 42′.4 per day, making 42°.4 in 60 days, roughly 43°. This also agrees with the angle for heliacal rising of Mars, nearly 17°, given by Hindu astronomy. (In 60 days the Sun moves 59.1°. So, the elongation is 59.1 − 42.4 = 16.7°, nearly 17°). If *viṃśatim* is taken as it is, we get 20° + 13° = 33°, which is 9.4° short of the actual 42.4 and which also gives the angle for heliacal rising as great as 26°, so far from the 14°-17° given by all.

In the mean, the motion from setting to conjunction must be equal to the motion from conj. to rising. That is why it is not given by the text separately. That the motion segments given in the two verses is mean is also clear, since no position of Mars from its apogee is taken into account. So the total motion must be equal to 409°. But the total got by adding the segments is 400°. This must be due to the defective method of the original or the empirical nature of the motions, and rounding off to whole degrees, as seen from 43° being given for 42.4°. The opposition must fall at the mid-point of the retrograde motion, − 18°, and divide it into −9, −9. The total motion from conj. to opposition must be equal to that from opposition to conj. But what we actually get is 43° + 146° + 18° − 9° = 198°, and −9° + 18° + 150° + 43° = 202°. It may be that the angle segments given are empirical and also there are errors in the apparently correct numbers giving the segments, needing emendation. It is only in the case of Mars, does VM give these eight types of motion. In II. 12-13 of the *Later Sūrya Siddhānta*, a set of 8 types of motion is given. But they cannot be equated to these each to each. So we have only to guess when in doubt. The days on the synodic cycles to pass each type of motion must be nearly equal to the average of the days given in verses 27-35 for that type of motion. This has been used to check the degrees of each type. But the synodic period, as also the mean motion of 1 + 18/133 revolution in that period are very nearly correct and they must have been got by analysis of the observed motions. So the *Siddhānta* must have known that the motions and times are half and half on both sides of the opposition.

Beginning from rising type I is *śīghra* (quick) motion. II is *manda* (slow) motion. The distinction seems to be faster or slower than the mean motion. So, the dividing point must be where the tangent from the earth touches the synodic circle. Since the mean distance of Mars is 1.53 times that of earth from Sun, this point falls about 189.5° from conjunction. Subtracting 43.5° motion from

25a. A. षट्चप्तस्तेक°; B. षट्वप्तस्तेक°;
D. षट्काष्टैकं; C. पदसप्तकं
b. A.B. °दशमस्तगस्ततो; C. °मष्टादशमासगस्ततो;
D. °दश वक्रगस्ततो
B. चक्रं; D. वक्रः
c. A.B.C. अत्यर्धं च ततः शीघ्रात्. D. गत्यर्थं च ततः शीघ्रात्
d. A.B.C. द्यु (B. घ्रा) नाषष्टिस्ततोस्तमितः;
D. त्रिघ्रषष्टिं ततोऽस्तमितः
26a. A.B.C. त्रियुता; D. त्रिहतात्
b. A.B.C. निरंशतो विंशतिं (B. विंशति)
D. [निरंशगस्त्रिंशतिं]
c. B. उदयेमुपयाति
d. A.B.C. द्यु (B. घ्रा) नाषष्टिस्ततोस्तमितः;

conjunction to rising (given as type VIII), 146° is left for type I. This segment extends upto the point where retrogression begins. As the planet is stationary, here a small error of observation can make this lesser or greater than the actuals. The text seems to give it as 18°. Types III and IV form the retrograde motion. III is called *vakra* (retrograde) and IV *ativakra* (faster retrograde). The text is defective here, and we cannot fix the exact extent of the two segments separately. But III and IV seem to be divided in the ratio 5:7 of the total. V is *anuvakra* (follow up after *vakra*). In the detailed motions given this is the sum of III and IV but direct motion. This *anuvakra* must be the counterpart of II. Type VI is *śīghra* and so the counterpart of I. Its extent is given as 150°. Type VII is the very quick motion from setting to conjunction and given as 43° in 60 days. Type VIII is the counterpart of VII from conjunction to rising. These divisions are mostly based on convention. But as these are given only in the case of Mars and classical astronomy does not give them, we have only to guess regarding them. To add to the difficulty the text is corrupt in the places giving the numbers.

TS have expressed inability to understand verse 25. Still, they have made some emendations which do not give any cogent meaning. No translation is given. There is only a question mark. In verse 26, they give 20° motion from conjunction to rising. This can give only 26 days, as against the 60 days given by the text. By this the elongation for heliacal rising would be 7 1/2°, so absurdly low.

As for NP, in both verses, they have needlessly emended correct forms, wrongly emended the corrupt ones, some in faulty Sanskrit and given an untenable scheme. The following is their scheme: Rising east / 186° motion / 18° retrograde motion / 180° motion / setting / 30° motion / Conj. / 30° motion / rising east. They have made the emendations and substitutions with their eye on the total motion of 409° in the synodic period. They make the total 408°, nearly correct. But they do not identify the vestiges of the different types of motion found in these verses. Further, 30° motion from setting to conj. and then from conj. to rising, is short by 12 1/2° from the actual 42 1/2°. The time required to move 30° is 42.2 days and the Sun would move 41.5° during this time, giving an elongation of 11.5° for heliacal rising, far short of the actual, especially for such high latitudes as the *Vāsiṣṭha-Pauliśa* envisages.

चत्वारिश (शच्छ)शि-न(ग)-[मु](न्य)-ष्ट-यमान्विता वि'पक्षा' च |
प्रथमगतौ (क्रमदि)वसा मीनाद्राशिद्वयसमानाः || २७ ||

27. In the I type motion, there are 40 + 1 (= 41), 40 + 7 (= 47), 40 + 7 (= 47), 40 + 8 (= 48), 40 + 2 (= 42), 40 − 2 (= 38), days per motion of 30° each respectively in each month of the diad of *rāśis* beginning from Mīna, (i.e. Pisces).

The above means, that for 30° of motion, the time taken is 41 days in the *rāśis* Mīna (Pisces) and Meṣa (Aries), 47 days in Ṛṣabha (Taurus) and Mithuna (Gemini), 47 days in Kaṭaka (Cancer) and Siṃha (Leo), 48 days in Kanyā (Virgo) and Tulā (Libra), 42 days in Vṛścika (Scorpio) and Dhanus (Saggittarius) and 38 days in Makara (Capricorn) and Kumbha (Aquarius).

27a-b. A.B.C.चत्वारिंशशिन (B.नु) मध्य (B. om. ध्य) ष्ट°
D.चत्वारि श [शत द्वयमष्ट] ° D. यमान्वितं विपक्षांशं

c. A.B. प्रथममतौ कुर्यादिवसा
C.D. प्रथमगतौ कुर्याद् दिवसा; (D. दिवसान्)

d. D. समान्

An examination of the rate shows that the perigee is situated at the end of the Makara (Capricorn) and the apogee at the end of Kaṭaka (Cancer), which both fairly agree with the actual.

TS say that they do not understand this verse, and no translation is given; its place being taken by a question mark. NP translate thus: "In the first gati 240 plus 28 minus ½ (= 267½) (days). One should calculate days for every two signs from Pisces." It is clear that they do not see that this verse gives the detailed rate of motion of the Type I *gati* in the diads of *rāśis* from Pisces, as affected by the equation of the centre. They think that the first motion given in verse 25, which 186° according to them, takes 267½ days, as given by them here. If so, what use is the instruction to calculate for "every two signs from Pisces"?

'विषय-[रस-] स्वर-(रस-)र्तु-पञ्चका[न्]'दशगुणान् द्वि[ती]यगतौ ।
सहितान्'स्वरैकपक्षर्तु-चन्द्र-शीतांशुभिः' क्रमशः ॥ २८ ॥

28. The II type motion, in the same order, (i.e. for each month of the diads, Pisces–Aries, etc.) for the 18° take 5 × 10 + 7, 6 × 10 + 1, 7 × 10 + 2, 6 × 10 + 6, 6 × 10 + 1, and 5 × 10 + 1 days.

This gives 57 days each to move in the signs Pisces–Aries, 61 days for each of Taurus-Gemini, 75 days for each of Cancer-Leo, 66 days for each of Virgo-Libra, 61 days for each of Scorpio-Sagittarius, and 51 days for each of Capricorn-Aquarius. From the days given, it can be seen that there is a slight tilt in the apogee towards Leo, and in the perigee towards Aquarius. This small difference from the findings in verse 27 shows that the values are empirical.

As for the readings, *rasa* has been inserted because we want six numbers for the six diads, and one is wanting. Symmetry requires that it must be *rasa* (= 6) there. Also two *mātrās* are wanting. *sapta* is emended into *rasa* because, 76 for Virgo-Libra, with 72 on one side, and 61 on the other side, will take the apogee to the end of Virgo, 60° off from its place.

The average for II type motion is 18° for 81 days which is about the average of the mean rate and 0 (stationary). Thus I type motion is faster than the mean, and the II type slower, as we have surmised.

TS have expressed inability to interpret this verse also, and not translated it. Yet they have made an emendation which need not be taken seriously, since it has been done without understanding.

NP have interpreted the verse as giving 57, 71, 72, 66, 61 and 51 by inserting *ṛtu* as the fourth. But symmetry shows that the second number 71 is wrong, and it must be 61, to avoid the jump from 57 to 72. At any rate, read with their interpretation of verse 27, we can see that they do not understand the use of this series of numbers. They do not even say these are days.

28a. A.B.C.D. विषयस्वरसप्तर्तुं (D. र्त्वृ)
b. A.B. पंचकाद्दशगुणाद्विवगतौ (B. °द्वियगतौ)
C. पञ्चैकाद्दशगुणान् द्विवगतौ; D. पञ्चकान् दशगुणान् द्वि[वी]यगतौ
c. A.B. सहिता; C.D. सहिताः;

झषवृश्चिकाज(चा)पेषु (वक्रं) षट्सप्तकेन (नव) भा(गान्) |
'(द्वि)कृतेन' (तैर्नवा)ऽतिवक्री दिनषष्ट्या षोडशानुगतिः || १९ ||
गोमिथुनतौलिकन्या(स्व'ग्निसागरैः स्व)रा'नंशान् |
'(त्रि)कृतैर्दश त्रिष (ष्ट्या)' सप्तदश यथाक्रमं वक्राशा[त्] || ३० ||
कर्कटसिंहयो'र्वेदसागरैः'सप्त '(रसार्णवै': 'शिवा'नंशान्' |
षट्(ष)ष्ट्याष्टादश क्रमात्कुजो वक्रपूर्वासु || ३१ ||
घटमृगयो'(र्नग)दहनैः' षड्भागा'(न्नवहु)ताश(नं)'(च) |
'मुनिविषयैः' पञ्चदशांशकांश्च तद्व(त् त्र)येऽप्यारः || ३२ ||

29. In the signs, Pisces, Scorpio, Aries and Sagittarius, Mars moves 7° in 42 days when retrograde (*vakra*) and 9° in 42 days when extra-retrograde (*ativakra*). In the follow-up after retrograde (*anuvakra*) Mars moves 16° in 60 days.

30. In the signs Taurus, Gemini, Libra and Virgo, Mars moves 7° in 43 days retrograde, 10° in 43 days extra-retrograde, and 17° in 63 days in the follow-up after retrograde.

31. In Cancer and Leo, Mars moves 7° in 44 days, 11° in 46 days, and 18° in 66 days, respectively, in the three types retrograde etc.

32. In Capricorn and Aquarius, Mars moves 6° in 37 days, 9° in 39 days, and 15° in 57 days, respectively, in the three types of motion.

29a. B.जष. A.जवापे; B.जपाचे
b. A.B.वक्रेषु; C.D.वक्रे षट्. B.षभ्दप्तकेन
A.नववभांग; B.नवभागा; D.षड्भागान्
c. A.B.विकृतेन दिनगति वक्री; C.द्विकृतेन नगान् वक्रे;
D.द्विकृतेन दिगति वक्रे
d. B3.षोडशा तु गतिः

30a. B.तौलिकं
b. A.B.॰नुवासनैः स्तरानंशान्; C.स्वब्धिसमुद्रैः
स्वरानंशान्; D.कन्यासु दशहतैः समुद्रैः स्वरानंशान्
c. A.B.खकृते; C.D.खकृतै A.B.त्रिषष्ठी
d. A.॰क्रमं वक्राशा ||; B.॰क्रमचक्रात् ||;
C.॰क्रमं वक्रात् ||; D.॰क्रमं वक्री ||

31a. C.सिंहकयोः
b. A.B.सप्तसप्तखा (B.ख) र्णवैश्च दिवसान्;
C.सप्तखार्णवैर्दिवसैः ||; D.सप्त भवान् खार्णवैश्च ||
c. A.B.C.D. add च at the end.
d. A.क्रामा कुजो; B.क्रमान कुजो. B.वक्रसर्वासु

32a. A.B.C.D.॰योर्यमदहनैः
b. A.B.नवव (B.वृ) द्गता शनैरैव व (ण. च);
C.D.नवहुताशनैश्च नव |
c. B.दशा
d. A.B.तद्वत्रये॰

Types III, IV and V, called, respectively, retrograde (*vakra*), extra-retrograde (*ativakra*) and follow-up after retrograde (*anuvakra*) are given in these verses. The first two are actual retrograde motion, and the third is the slow direct motion following. They are shown hereunder in a tabular form.

Signs	Pis-Ari	Tau-Gem	Can-Leo	Vir-Lib	Scor-Sag	Cap-Aq
Type III	−7°/42 d	−7°/43 d	−7°/44 d	−7°/43 d	−7°/42 d	−6°/*37* d
Type IV	−9°/42 d	−10°/43 d	−11°/*46* d	−10°/43 d	−9°/42 d	−9°/39 d
Type V	+16°/60 d	+17°/63 d	+18°/66 d	+17°/63 d	+16°/60 d	+15°/57 d

The division into the three types is arbitrary, based on some convention. By examining the table we can see two things note-worthy. The total of arcs of III and IV is equal to V, though V is positive. The days for III and IV are the same, except for Cancer-Leo, and Capri-Aquarius. There is symmetry on both sides of these sets. Guided by the above, I have emended certain numbers which glaringly go against these points. In verse 29, *nava* for *vakra* is corrected into *naga* since it must be less than the 9° given for *ativakra*, and both equal to 16°, clearly given for *anuvakra*. In verse 30, the corrupt *stara* is changed into *svara* to make up the total 17°. The corrupt *nuvāsanaiḥ* is amended into *agnisāgaraiḥ*, guided by symmetry. *Khakṛteḥ* is emended into *trikṛteḥ* since the number should be greater than 42, by symmetry. In ver. 31 the corrupt *sapta khārṇavaiśca divasān:* is corrected into *rasārṇavaiḥ śivān aṃsān* because 11° required to make up the total 18° for *anuvakra*. *sapta* is a repetition, *khārṇavaiśca divasān* = 40 days, does not fit, since the maximum number of days is requred there, and 46 fits eminently. In verse 32, *yama* is corrected into *naga* since *yamadahanaiḥ* (= 32) is too short a period, and far from the 42 days on both sides, and the number should also be a little less than 39. *reva ca*, corrupt, is emended into *nava ca*, which will make up the total 15° of *anuvakra*.

वक्रे दिनत्रिभागैर्नवांशयुततुल्यजिनैर्भुक्तैः ।
अतिवक्रे विपरीतं वक्रमनुवक्रगस्त्र्यंशम् ॥ ३३ ॥

As for verse 33, the words in it are all perfect, without any corruption. But they do not make any sense. It seems that some rules are given here for the division into the three types with their days, and the proportion is roughly 5:7:12, of the degrees of all three combined. At any rate, this instruction does not seem to serve any purpose.

Ativakra represents the faster retrograde motion near opposition *plus* the slower *vakra* motion on the other side. That is why it is greater and faster. But why exactly the same number of days? This seems to be a convention. But this is against logic. For, only in Cancer-Leo, and Capricorn-

33b. A. नुल्य
D. नवांशयुतैस्तुल्य॰ B. जिह्रोर्भुक्तेः;
D. जिह्रैर्भुक्तैः
c. A1. अतिवक्ते; B. अतिचक्रे B2. विपरितं
d. B. वह्नुमनुगसत्र्यंशं; D. ॰मतिवक्रं सत्र्यंशं

Aquarius, there is a small excess of days for *ativakra*, but even this is far too small. The sum of *vakra* and *ativakra* is 18° and a maximum at Cancer-Leo, and minimum 15°, at Capricorn-Aquarius, and fairly evenly distributed in between. But actually, at Capricorn-Aquarius, the sum is near 9°, as a comparison with the motion of Mars given in the *Vākyakaraṇa* will show (*vide* App. III, *Kujavakra*, where retrograde occurs in the signs Capricorn-Aquarius).

TS have translated verses 29-32, omitting verse 33 as obscure. But they think that all three types are retrograde motion, (while actually only III and IV are retrograde, and V is direct motion). This would make the range of the retrograde motion from 36° in Cancer-Leo to 30° in Capricorn-Aquarius, while the range given is 18° to 15°, actually the latter is even as small as 9°. Also, they do not see that the IV type should be greater than the III. So they give the numbers as they got from the words, instead of emending them appropriately. So, in verse 29, *navabhāgam* as emended by them should be *navabhāgān*. *nagān vakrī* should be *navātivakrī*. In verse 30, their emendation *abdhisamudraiḥ* should be *agnisāgaraiḥ Khakṛtaiḥ* should be trikṛtaiḥ. In verse 31, their *khārṇavair divasaiḥ* giving no degrees at all for the days, and defective in *mātrās* should have been emended into *rasārṇavaiḥ śivānaṃśān*. In verse 32, symmetry requires our emendation of *yamadahanaiḥ* into *nagadahanaiḥ*, while TS have kept it.

As for NP, they have understood that type III gives retrograde and type IV, extreme retrograde, though the numbers they give for degrees and days are untenable in many cases. Seeing that the degrees of V are the sums of those of III and IV, they think that V is the total of the retrograde motions, while actually V is direct motion. They do not see that if the degrees of V are the total of III and IV, the days too must be the sum of the days, and therefore V is not the total retrograde. They have translated verse 33, but this does not give any sense.

'एकेन्द्रियवसुशिवमनु[मनु] भव त्रिवर्गर्तु(पञ्च)'संयुक्तम् |
शीघ्रगतौ पञ्चाष्टकमूनं च 'शशाङ्ककृतवेदैः' || ३४ ||

34. In the quick motion following *śīghragati* (= type VI), there are the days, 40 + 1, 40 + 5, 40 + 8, 40 + 11, 40 + 14, 40 + 14, 40 + 11, 40 + 9, 40 + 5, 40 − 1, 40 − 4 and 40 − 4 for every 30 degrees.

Obviously, these days are given for each one of the signs beginning from Pisces. The numbers are almost perfectly symmetrical on both sides of the inter-section of Cancer-Leo, and Capricorn-Aquarius, re-inforcing the conclusion that the former intersection in apogee, and the latter perigee.

manu for Leo is a glaring omission and is inserted. Symmetry requires 45 for Scorpio, and so *pakṣa* is emended into *pañca*. The number-words forming a *'dvandva'* compound, *trivargam* is wrong for *trivarga*, and so has been emended. –*tu* is removed being an extra *mātrā* and purposeless. This verse is of the same kind as verses 27, 28 combined, giving types I and II.

TS have not understood what is given here, and its purpose, as they have not understood the corresponding verses 27-28. But they have translated this verse as the words go, and wrongly too, the numbers given by them forming a mere jumble, without any instruction, 2 + 1, 2 + 5, 2 + 8, 2 + 14, 2 + 11, 2 + 9, 40 − 1, 40 − 4, 40 − 4. No wonder, they append this with a question mark.

34a. A.B.C.D. Hapl om. of one मनु
A.B.C. पक्षसंयुक्तम्; D. पञ्च संयुक्तं
b. A.B.C.D. भवत्रिव (B.om व) र्गं (B2.ग्रं) तु (A2.B1.2. नुः D. वर्गर्तु
c. D. पञ्च षष्टिं
d. A. °मूनं व B1.3. तत्तवेदैः; B2. ततवेदै

NP have emended the already correct *pañcāṣṭakam*, meaning 40, into *pañcaṣaṣṭim* which they think would mean 5 × 60 = 300. *pañcaṣaṣṭim* would mean only 65. To mean 5 + 60, the form should be *pañcaṣaṣṭayaḥ* (nominative) or *pañcaṣaṣṭiḥ* (accusative). The trouble is that they have not understood that the days given are for every 30°, everywhere except in types III, IV and V. That is why they make such un-authorised corrections and give wrong translations.

षट्त्रिंशत्संयु(क्ता) ('ह्यनलाङ्कार्क) त्रिवर्गगुणशून्यैः' |
दिवसाः सप्तमगत्यां चा(रो) य[द]त्र [त]द्वदष्टम्याम् || ३५ ||

35. In the VII type, (i.e. *atiśīghra*), for every 30° of the diads Pisces-Aries, Taurus-Gemini, etc. there are the days, 36 + 3, 36 + 9, 36 + 12, 36 + 9, 36 + 3, 36 + 0. The motion as given for the VII type is for the VIII type too.

Here too the symmetry on both sides of the apogee, and perigee is necessary, and the corrupt *dvikalāhvārkā* is corrected into *hyanalāṅkārka*, corresponding to *trivargaguṇa*. This forms the motion from setting to conjunction. As the VIII type, forming the motion from conjunction to rising is exactly the counterpart of the VII in the synodic cycle, it follows that type VIII is the same.

TS have emended *dvikalāhvārkā* into *dvyanalāṅkārka*, resulting in 7 quantities of days, while only 6 are wanted for the diads of signs. NP, here too, as in verse 34, have made an unauthorised correction under the same mis-apprehension. They have substituted *ṣaḍbhiś ca* for the correct *ṣaṭ-triṃśat*. They do not see the contradiction this leads to. From setting to conj. or from conj. to rising the days they give are not less than 60, 66, on the average. For this, the average motion would be about 46° in this region of the synodic cycle. But they have interpreted that it is 30°, in verse 26. They have not seen the contradiction.

As I have done for Jupiter and Saturn, here too, I shall work out an example, to make my explanations clear.

Before closing, I wish to say something about Mercury. The case of Mercury is as involved as that of Mars, but in a different way. In one sidereal year Mercury traverses three full synodic cycles and more. But it moves in the zodiacal circle together with the Sun in the mean and its equation of the centre depends on its position in the 12 signs. So the motion types vary from synodic cycle to synodic cycle in the same year, needing a large number of day-groups, and these are given by VM. But it is these numbers that are spoiled by scribes most and the reconstruction is a tedious job. (The methods, though sometimes peculiar, can be guessed and explained). I have neither the leisure nor the equanimity of mind to undertake this work at present, *and hope someone else* would do it.

35a. A.B. षट्त्रिंशस्तंयुक्ता;
D. [षष्टिभिश्च] संयुक्ता
b. A.B. द्विक (B. फ) लाह्वा (B. ह्वा) -र्का;
C. ह्यनलङ्कार्क; D. ह्यनिलाङ्कार्क
A.B. गणशून्यैः
d. A. चावो यत्र; B. चारो यत (B2. यत)
A. यत्र द्वदष्टम्यां
C.D. यस्तद्वदष्टम्याम्

Example: Find true Mars at 800 days from Epoch.

Days from Epoch	800 – 0 – 0
Subtract days at first rising	256 – 40 – 0
	543 – 20 – 0
No. of revolutions gone	$\frac{543\text{-}20}{700} = 0$
Remainder	543 – 20 – 0
Correction for revolutions gone	0 – 0 – 0
Days after rising	543 – 20 – 0

$$\text{Mars at rising} = \frac{18 \times 0 + 85}{133} \text{ revolutions} = 230°, \text{ i.e. } 20° \text{ in Scorpio.}$$

Starting from this point, i.e. 20° in Scorpio at rising, true Mars moves in 543-20 days, as per the scheme given in verses 24-35, to 29° 47′ in Cancer as per details given below:

Type I: 146° Total days = 543-20

Balance 10° in Scorpio	14 days	$(\frac{10}{30} \times 42)$
30° in Sagittarius	42 "	
30° in Capricorn	38 "	
30° in Aquarius	38 "	
30° in Pisces	41 "	
16° in Aries	21 + 52	$(\frac{16}{30} \times 41)$
Total	194 + 52	
Balance No. of days	....	..........348.28

II: 18°

14° in Aries	44-20	$(\frac{14}{18} \times 57)$
4° in Taurus	13-33	$(\frac{4}{18} \times 61)$
	57-53	
Balance No. of days	....	290-35

III: 7° (Retrograde)

– 4 in Taurus	24-34	$(\frac{4}{7} \times 43)$
– 3 in Aries	18-00	$(\frac{3}{7} \times 42)$
	42-34	
Balance No. of days		248-1

IV: 9° (Fast Retrograde)				
	– 9 in Aries	42-00		
	Balance No. of days			206-1
V: 16°	12° in Aries	45-00	$(\frac{12}{16} \times 60)$	
	4° in Taurus	14-49	$(\frac{4}{17} \times 63)$	
		59-49		
VI: 85° 47′	26° in Taurus	41-36	$(\frac{26}{30} \times 48)$	
	30° in Gemini	51-00		
	29° 47′ in Cancer	53-36	$(\frac{53\text{-}36}{54} \times 30)$	
		146-12		

Therefore, True motion in 543-20 days from 20° to 29° 47′ Cancer = 249° 47
Mean motion in 543-20 days: 408 – 43 × 543 1/3 /780 = 284° 42′

Therefore days to be added = 34-55

True motion for 34-55 to be added
In Cancer 0-13′ for 0-23, and for the balance 34-32 days,

In Leo $30 \times \frac{34\text{-}32}{54} = 19° 11'$

Therefore True Mars: 19° 11′ in Leo.

Motion of Mercury[1]

As in the case of other planets, the epoch date is so selected that Mercury rises heliacally in the west on that date. Since, for Mercury, the elongation required for heliacal rising is given as twelve degrees, on the epoch day its longitude is 12 degrees ahead of the Sun. Then, the number of days elapsed from the epoch is obtained and divided by the sidereal period of Mercury, so that the resulting quotient represents the number of risings that had taken place since the epoch, and the remainder the number of days elapsed in the current sidereal cycle.

The movement of Mercury in one synodic period being known, (given by the text), the total longitude moved during the elapsed number of risings is also known and adding to this the epoch constant, that is, the position of Mercury on the epoch day, its longitude on the day of the current rising is obtained. However, these figures are on the assumption that the motion of Mercury is uniform, which is not the case. So, what we have got is only the mean position of Mercury and not its true position. Here, as also in the text, 'mean position' does not mean the mean heliocentric position as we now understand, but the mean geocentric position on the assumption of uniform motion. The true position varies from the mean by quite a few degrees. The date of rising also is only a mean date and the true date may be several dates behind or ahead.

1. Mercury : Translation and Notes by S. Hariharan, Bangalore.

The text then gives a table from which for a given mean longitude the true position on the true date can be obtained. Since the Sun's position has to be 12 degrees behind the true position of Mercury, the same correction applied to Mercury has to be applied to the Sun. That means, keeping in mind that the Sun moves one degree in one day approximately, the true date is ahead of the mean date by as many days as the number of degrees in the correction, if the correction is positive, and vice versa. Consequently, the number of days elapsed since the (true) rising is also modified by the same number of days, reduced, if the correction is positive, and vice versa.

Having got the true Mercury as on the true date of rising and the number of days elapsed since rising, we have now to get the degrees moved by Mercury during these remaining days in the synodic cycle. For this purpose the synodic period is divided into several sections just as in the case of other planets. In the case of Mercury the division is made into four sections or *gati-s*. The first is from rising to starting of retrogression, the second is the period of retrogression, the third is from end of retrogression or *anuvakra* to setting, while the fourth is from setting in the east to rising in the west. The number of days for each section and the movement are not constant but vary depending upon the position of Mercury in the zodiac. Accordingly, tables giving these values for each of the twelve signs are given in the text. With the help of these tables we can trace the movement of Mercury during the remaining days and finally arrive at its position.

What is new in the case of Mercury is the method of interpolation within these tables. For other planets no specific method of interpolation is suggested, with the result we assume linear interpolation. But here a second degree interpolation is suggested for certain sections.

TS and NP do not appear to have understood the procedure nor the rationale expounded by these verses, as could be gauged from the emendations they make and explanations they give to the verses.

[बुधमध्यम्] [बुधचारः]

(दद्यात् सप्तचतुष्कान्) द्युगणे त्र्यंशं च 'वसु'गुणो भागः |
'मुनियमनवकै'रपि (रौहिणस्य) वेद्या, दिनाष्टांशाः || ३६ ||
[हत्वा] चतुर्भिरुदयान् नाड्यः शोध्या बुधस्य दिवसेभ्यः |
'त्रिरसयम'घ्नानुदयान् 'रामार्णव' वर्जितान् छिन्द्यात् || ३७ ||
'नवयमवसु[भि]र्मध्यमथो सक्रमानुदयांशैः क्रमाद् |

Mean Mercury

36-38a Add to the *ahargaṇa* seven times four, i.e., 28, and a third. Multiply by eight and divide by 927. The quotient is the risings of Mercury. Take the eighth part of the remainder and deduct therefrom, in *nāḍikās*, one fourth of the risings, and the result is the (remaining) days of Mercury. Multiply the ris-

36a. A.दद्या B.सप्रनुक्कान्
b. B.द्यगणो A.त्र्यंशः; B.त्र्यंश
B.गुणभागः D.भाज्यः
c. A.नचकै
d. A.B.रोचितस्यः C.रोहिणस्य; D.रोचिताः स्युः
A.मेद्या; B.मेधा; D.शोध्यो
D.दिनाष्टांशः
37a. A.B.कृत्वा
b. A.दुधस्य; B.बुछस्या
c. A.B.त्रिदशयमघ्नान्; D.[अद्रिदशयम]यमघ्नान्
B.॰नुदयां
d. B.रामणववर्जितान्; D.पाण्डववर्जितै श्छिन्द्यात्

ings by 263, deduct 43 and divide by 829 and the result is the mean Mercury (in revolutions).

These will lead to the following:

i. 28 1/3 days before the epoch, Mercury rises in the west, after which the countings of the risings begin.

ii. One synodic revolution takes (927/8 + 1/240) days. The deduction of ¼th *nāḍī*s or 1/240th day per rising is for taking the synodic period as approximately 927/8 days. The balance remaining after division by 927 is the number of eighth parts of a day elapsed since the last rising. So, dividing this by eight, the number of full days are obtained. During a synodic period the motion of mean Mercury is equal to 263/829 revolutions (which is the same for Sun). Hence for one full revolution Sun will take,

$$(927/8 + 1/240) \times 829/263 \text{ days, or, } 365.261708 \text{ days, i.e., } 365\text{-}15\text{-}42.$$

iii. At the epoch date, that is 28 1/3 days before 20-3-505 AD., Sun's longitude is 357-37 *minus* 27-55 or 329-42.

iv. On this date, Mercury's longitude is given by:

(No. of risings (zero) × 263 − 43)/829 or − 43/829 revolutions. This reduces to − (18-40), or 341-20, which is ahead of Sun by 11-38 as against 12 needed, and therefore acceptable.

In verse, 36c, we, also others, have emended the ms. reading *muniva.nanaca* as *muniyamanava* to get the correct figure 927. In 37a *kṛtvā* has been made as *hṛtvā*.

The meaning and rationale of these verses is clear. But NP have made *medhā* in 36d as *śodhyo* and have translated it as "Subtract an eighth part of a day (for every synodic period)" etc. and comment, "We find in XVII, 36 a subtraction of 1/8 of a day and a division of the number of risings by 4. We cannot explain these steps which seem in excess of the normal procedure."

It is rather surprising that NP missed the elementary step of dividing the remainder by 8 to get the number of days, particularly when TS have correctly interpreted it. Without the correct number of days (elapsed since the last rising) the further processing does not make sense. Hence we feel that NP have not understood the process at all.

In the next step of finding the longitude of Mercury at the time of the last rising, the figures in the verses have been badly corrupted. In 37b *tridaśayama* has been emended as *tridivasapa* by TS, and in 38a *navavasuyama* as *navavasurāma*, so as to give them a multiplier of 123 and divisor of 389. But this would give the Sun's period as 366.479641 days which cannot be.

NP have made *tridaśayama* as *adridaśayama; rāmārṇava* as *pāṇḍava* and *navavasuyama* as *navavasurasa*. They have also changed the meaning so as to subtract *pāṇḍava* (5) from the divisor 689 rather than to make the deduction from the product. All these they have done just to make these constants agree with those of Babylonian and then claim that "Table 24 reveals exact numerical agreement for the outer planets and Mercury" (!). They forgot that in this process they have obliterated the initial epoch constant of the longitude of Mercury and comment "For Mercury we have no epoch constant giving us directly a longitude."

We have emended *tridaśayama* as *trirasayama*, and *navavasuyama* as *navayamavasu*. As shown above, these numbers give the sidereal period of Sun as 365-15-42, which is within limits. Of

course, the constants as emended by NP also will give the correct sidereal period, namely, 365-15-35, as it should be, but the emendments made are too violent.

[बुधस्फुटः]

पञ्चयुतैस्त्रिंशद्भिस्त्रिंशद् [भुङ्क्ते] स्फुटानंशान् || ३८ ||
'नव (षष्ट्या) षष्टिः [स्यात्] 'वसु'युताशीत्या शतं (वितीक्ष्णांशुः) |
सर्वैस्त्रिभिरभ्यधिकैस्त्रिंशद्भिस्त्रिं (शद्युताश्चांशाः) || ३९ ||
चतुरधिकेन शतेना [र्कयुतं] शत, मतोऽ'र्थ'संयुतया |
षड्विंशत्या त्र्यधिका त्रिंशतिरेवं स्फुटः सौम्यः || ४० ||

True Mercury

38c-40. For the rising degrees in order, we have

for 30 +	5	35 degrees		30 degrees
9 +	60	69		60
8 +	80	88	100 − 12	88
3 +	30	33	30 + 7	37
4 +	100	104	100 + 12	112
5 +	26	31	3 + 30	33
Total		360		360

Thus true Mercury.

We have made some minor emendations like *navakṛtyā ṣaṣṭim* to *navaṣaṣṭyā ṣaṣṭiḥ, ca tīkṣṇāṃśum* to *vitīkṣṇāṃśuḥ, triṃśadbhuṅkte* for *triṃśadbhakta*, to get the total as 360 for both sides as they should be. With this table corresponding to the mean mercury obtained as per the previous verse the true mercury can be got. This is for the true date of rising. Now, the true date has to be obtained or, what is the same as getting the true remaining days passed after the true rising date. This is dealt with in the next verse.

38a. A.B. नववसुयममध्य (B. rep. यममध्य) मद्यो:
C.D. नववसु रामै मध्यं D. [मध्यमो]
b. A. सा क्रमांनुदशैश्च; B. शक्रमाह दशैश्च
D. [बुधोऽष्टांशान् क्रमादहर्दस्त्रैश्च]
38c. B3. Hapl.om. युतै [स्त्रिंशाद्भि] स्त्रिं°
d. - A.B त्रिशद्धक्तस्फुटानंशान्

39a. A.B. नवकृत्यात् षष्टिः; C.D. नवकृत्यात् षष्टिं
b. A.B. युतयावशीत्या. A.B. शतं सतीष्णांशोः;
C.D. शतं सतीक्ष्णांशुम्
c. C.D. शर्वै. A. रभ्युधिकै
d. A.B. त्रिशदेवार्कान्; C.D. त्रिशदेवांशान्

40a. A1. चतुरधिकेन्. A.B.C.D. शतेन त्रिभिरूनं
c. A.B.C.D. त्र्यधिकां
d. A.B.C.D. विंशतिमेवं

These verses actually give the true longitudes at the time of rising corresponding to mean longitudes. The mean longitude is obtained as per the previous verse.

TS and NP think that, in verses 38b-40, the true motion of Mercury is given, for certain days certain degrees, and so on. They have made some emendments of their own and both of them get the total degrees moved as 360 but as for the number of days TS get 389 while NP get 388. The 389 of TS is the same as the divisor of the previous verse and so they think that corresponding to the remaining days which will be upto 389 these verses give the true *śīghra-sphuṭa*. But their idea is vague and they are not able to expand it properly.

NP think that what is given is an eightfold division of the ecliptic but they are not able to explain anything further. They comment, "The text calls n1 'days' which, in any case, is meaningless". In fact there seems to be no reference to days at all in these verses.

अनयोर्विश्लेषांशान् दिवसेभ्यः शोधयेत् स्फुटाभ्यधिके |
अधिके.तु (मध्यमेंऽशान्) दद्याच्चारः स्फुटबुधाच्च || ४१ ||

41. Deduct from the days the degrees of difference of these two, (i.e., of the mean and true places of Mercury), in case the true place is in excess of the mean place, and add if the mean is in excess of the true. Then the course of true Mercury is as follows.

TS and NP have not been able to appreciate the rationale for this operation. TS have not given any rationale. NP think that the correction applied to the days is a mistake and it should be applied to the longitude; and the correction to the days should be applied by dividing the correction (in degrees) by the synodic motion per day. This however is not the correct position.

Since this relates to the rising position of Mercury on the true date the Sun will be 12 degrees less than the true Mercury. So the Sun also will have to be corrected by the difference between the true and mean positions of Mercury. Since the motion of the Sun can be taken as one degree per day for small durations, to that extent of the difference the rising date will shift. If the true Sun is in excess, the date will get advanced, and, consequently, the remaining days will get reduced, and vice versa. Obviously the number of days will be equal to the number of degrees.

Note on Verses 42-53

These verses give the *gati*-s of Mercury relating to the twelve signs, Aries to Pisces. In each verse, the first quarter gives the degrees (days) of motion from the rising of the planet to the commencement of retrogression, the second quarter for the period of retrogression, the third for the period from the end of retrogression to the setting of the planet and the fourth from setting to its rising. In order to check the accuracy of the figures, they have been calculated by modern methods. The

41a. A.B. ०षांशा
b. A. शोधये स्फु. C. धिके च.
c. A.B. repeat after b, verse 40, with a few variants, as: चतुरधिके पञ्चशतेन तिरूनं and धिशतिरेवं.
c. A.B. मध्यमे स्या
d. A.B. दद्याच्चार (B1.2. चारः)

textual figures might be seen to agree with the calculated figures in several cases with minor differences, of course on account of the constants used in *Pauliśa* and *Vāsiṣṭha*, and due to observational errors. Where they differed widely, it has been examined whether there could be due to defective readings and suitable emendations have been suggested in consonance with the reading of the manuscripts, as far as possible. Neither TS nor NP appear to have understood the purport of these verses and have suggested all sorts of emendations. TS do not translated at all verse 54.

[मेषः]

मेषे 'दिन'षट्कृत्या' 'शिव'-'भव'-'ख'-'द्विसप्त' हीनया (भागाः) |
'पञ्चविंशत्'-'त्रिः''कृत'-'षट्सप्तक'-'त्रिवर्गैरिषु'गुणितम् || ४२ ||

Mercury's gatis for Aries

42. The *gati-s* in Aries are:

	Degrees	Minutes	Textual °	Textual ′	Calculated °	Calculated ′
1. Rise to Retro.	36 − 11=25	25	25	25	23	26
2. Retro.	36 − 11=25	3 × 4=12	25	12	24	11
3. Retro. to Set.	36 − 0=36	6 × 7=42	36	42	39	44
4. Set. to Rise	36 − 14=22	3^2× 5=45	22	45	22	45

[वृषभः]

गवि 'वेद'-'द्वि'-'कृत'-'यमा'-हिघ्नै'-'ख'-'वस्व'-'ग्नि'-'गुणाभ्यधिकैः |
वि'रसं' शतार्धमूनं 'रुद्रा'-'मर'-'सप्तभि'-'र्व्येका || ४३ ||

43. In Taurus, the *gati-s* are:

	Degrees	Minutes	Textual °	Textual ′	Calculated °	Calculated ′
1. Rise to Retro.	4 × 8+0=32	44 − 11=33	32	33	31	34
2. Retro.	2 × 8+8=24	44 − 33=11	24	11	24	9
3. Retro. to Set.	4 × 8+3=35	44 − 7=37	35	37	33	36
4. Set. to Rise	2 × 8+3=19	44 − 1=43	19	43	20	43

42a. A.B.2.3. कृत्यां; B1. षट्कसा
b. A.B. शंभव; C.D. समुवा (D. समव) सप्त.
A.B. भागः; C.D. भागान्
c. A.B. विकृति; C. त्रिकृति;
D. द्विकृतिं
d. A.B.C.D. त्रिसप्तकं. A.B. षड्वगैव (B. षट्दव)
गणितं (B. गणित); C. षट्कमिषुगुणितम्;
D. षडङ्कगुणितम्.

43a. A. गाव; B. माव. A1. वेदे; A2-दे.
A. कृतो; B. ततो;
C.D. वेदयमद्विकृतैः
b. A.B. द्विघ्नैः; C.D. दिग्घ्नैः.
A.B.C.D. विषयाग्निगणनवाभ्यधिकैः;
c. A.B. शतार्धममलो; C.D. शतार्धममरैः
d. A.B. रुद्रावथ; C. रुद्रेरथ; D. रुड्रूनं च.
C. सप्तभिर्हीनम्; D. सप्ततिं व्येकाम् |

[मिथुनम्]

द्विदशं सपञ्चवर्गं [त्रि-रस-गुणा]न्वितं च मिथु(ने) च |
भागार्धशत(द्व्यूनं) 'मुनय' - 'स्त्रिघनं च [पञ्चवेदाश्च] || ४४ ||

44. In Gemini, the *gati-s* are:

	Degrees	Minutes	Textual		Calculated	
			°	′	°	′
1. Rise to Retro.	20 + 25=45	50 − 7=43	45	43	38	42
2. Retro.	20 + 3=23	3	23	3	23	8
3. Retro. to Set.	20 + 6=26	3^3 =27	26	27	27	29
4. Set. to Rise	20 + 3=23	45	23	45	21	45

[कर्किः]

(कर्किणि 'दिग्घ्नैः') ['कृता'-'श्वि'-'गुण'-'पक्षैः']स('दि-'ग')-'ष्ट'-'शून्य'-'रसैः' |
('सेभान्') 'दलितान्' ('सेन्दून्') 'पञ्चकवर्गान्विता'नंशान् || ४५ ||

45. In Cancer, the *gati-s* are:

	Degrees	Minutes	Textual		Calculated	
			°	′	°	′
1. Rise to Retro.	8 × 4+8=40	40 + 7=47	40	47	42	48
2. Retro.	8 × 2+8=24	24 × ½=12	24	12	24	10
3. Retro. to Set.	8 × 3+0=24	24 + 1=25	24	25	22	24
4. Set. to Rise	8 × 2+6=22	22 + 25=47	22	47	23	47

[सिंहः]

सिंहे ('बाण'-गुणा'-क्षि'-'रामैः''दिग्'घ्नैः 'सार्णवे'-'न्दु'-'यम'-'विषयैः' |
(सप्ताधिकां) दलितां स('कृता')मधिकां 'विषय'कृत्या || ४६ ||

44b. A.B.C.D. स्वरसघनान्वितं A.B. मिथुनं च
c. B. शत; C.D. शतं. A.B. घून; C.D. द्व्यूनं
d. A. पवसुतश्च; B. त्रिघनपवसु and indicated omission upto सप्ताष्ट of verse 47c below; C. पञ्चवसु; D. पञ्चसप्त

45a. A. कर्किनि. A.B. दिघ्नैः
b. A.C.D. कृतशशिगुणवेदैः सद्विकाष्टशून्यरसैः
c. A.C.D. सैकान्. A. सेन्दु
d. A.C.D. पञ्चकवर्गान्वितांश्चांशान्

46. In Leo, the *gati-s* are:

	Degrees	Minutes	Textual		Calculated	
			°	′	°	′
1. Rise to Retro.	5 × 8+4=44	44 + 7=51	44	51	44	51
2. Retro.	3 × 8+1=25	25×½=12½	25	12½	25	12
3. Retro. to Set.	2 × 8+2=18	18 + 4=22	18	22	19	22
4. Set. to Rise	3 × 8+5=29	29 + 25=54	29	54	28	52

[कन्या]

कन्यायाम् 'ऋतु(कृत')-'त्र्यष्टक'-['विंशतिस्']-('त्रिंशतिः सभूतः') |
'त्रिघन[द्वय]'-'नवपञ्च[क'-'त्र्यष्टकं'] 'शतार्धं च (नव)युक्तम्' || ४७ ||

47. In Virgo, the *gati-s* are:

	Degrees	Minutes	Textual		Calculated	
			°	′	°	′
1. Rise to Retro.	46	$3^3 \times 2=54$	46	54	44	52
2. Retro.	24	9 × 5=45	24	45	23	14
3. Retro. to Set.	20	3 × 8=24	20	24	19	23
4. Set. to Rise	35	50 + 9=59	35	59	35	59

[तुला]

'विंशतिरेकेन युता' [हीना] 'खा'-'शा'-'ष्ट'-'खा'दिभिर्द्विसंगुणाश्च |
अंशास्त्रि[युता] 'वसु'विहीना ह्येक-त्रयोविंशद्युता चैव || ४८ ||

46a. A.C.D. गुणेन्दुरामार्णवदिग्घ्नैः (D. र्णवैर्दिग्घ्नैः)
b. A.C.D. सार्णवर्तुयम. A. विषयाः
c. A.C.D. तुल्यां (A.B. तुल्या)
at the commencement of the line.
A.C.D. सप्तविहीनां
d. A.C.D. सदृशा॰ (A. सदृशां)

47a. A.C.D. कन्यायामृतुकृत्या
b. A. ष्टत्रिंशत्तया तया न भूतः; C. ष्टत्रिंशता तया तयात्र भूयः;
D. ष्ट[दशत्रि] त्रिंशं त्रिकृतैर्न भूयः
c. B1.2.3. commerce again with सप्ताष्टकं शतार्धं, after the indicated gap.
A.B. सप्ताष्टकदशशतार्ध च रवियुक्तम्,
C.D. सप्ताष्टकं शतार्धं (D. ष्टकमष्टशतार्धं) च रवियुक्तम् | for ॰कत्र्यष्टकं etc.

48. In Libra, the *gati-s* are:

	Degrees	Minutes	Textual		Calculated	
			°	′	°	′
1. Rise to Retro.	(21 − 0)×2=42	42 + 3=45	42	45	39	47
2. Retro.	(21 − 10)×2=22	22 − 8=14	22	14	21	15
3. Retro. to Set.	(21 − 8)×2=26	26 + 1=27	26	27	24	27
4. Set. to Rise.	(21 − 0)×2=42	42 + 23=65	43	5	42	5

[वृश्चिकः]

अलिनि दशघ्नाः [त्रि]-'शशि'-('शिखि')-'कृताः'('षडी'-'शा'-)'र्णवा'-('क्षि')-युताः |
तेंऽशा 'यम'युता 'मुनि'विहीना 'त्रि'-'षड्''विंशत्या' (समेताश्च) || ४९ ||

49. In Scorpio, the *gati-s* are:

	Degrees	Minutes	Textual		Calculated	
			°	′	°	′
1. Rise to Retro.	10×3+ 6=36	36 + 2=38	36	38	35	39
2. Retro.	10×1+11=21	21 − 7=14	21	14	21	16
3. Retro. to Set.	10×3+ 4=34	34 + 3=37	34	37	33	38
4. Set. to Rise	10×4+ 2=42	42 + 26=68	43	8	43	6

[धनुः]

धन्विनि द्विदशावष्टौ, [विंशं], षट्सप्तकं, 'कृतोनं' च |
ते ('इषु'युत)'विषयोनाः '('शैला': त्रिंशा)न्विता भागाः || ५० ||

48a. A.B. रेकेण
b. A.B. व्यनखांसां तिथिद्विसंगुणैश्च; C. हीना खाशाग्निभिर्द्विसंगुणाश्च; D. युता जूके सशून्यतिथिर्द्विसंगुणाश्च |
d. A.B.C.D. ह्येक (A. द्येक) त्रिंशद्युताश्चैव |

49a. A. दशाघ्नी; B. दशघ्ना
b. A.B.C.D. शशिकृत (B. om. त, D. शशिद्विकृत) for त्रिशशि. A.B. दहनाः षड्स्वरार्णवाष्टयुताः; C. दहनयुगा वसु-शरार्णवाष्टयुताः; D. दहनाः शरार्णवाष्टयुताः |
c. A. तेशा; B1.3. तेषां. A.B.D. यममुनीशोना; C. यममुनीशेन
d. A.B. समेना व (B. च)

50. In Sagittarius, the *gati*-s are:

	Degrees	Minutes	Textual °	Textual ′	Calculated °	Calculated ′
1. Rise to Retro.	2×10+ 8=28	28 + 5=23	28	33	28	32
2. Retro.	20=20	20 − 5=15	20	15	20	16
3. Retro. to Set.	6× 7 =42	42 + 7=49	42	49	42	50
4. Set. to Rise	6× 7− 4=38	38 + 30=68	39	8	39	3

[मकरः]

मकरे द्विदशं ['त्रि']-'ख'-युतं 'मुनि'युत 'धृति-'दिवाकरा'भ्यधिकम् |
(अंशा 'र्णव'-युता हीना) ('शैला')-'श्चोत्कृति'युताश्च || ५१ ||

51. In Capricorn, the *gati*-s are:

	Degrees	Minutes	Textual °	Textual ′	Calculated °	Calculated ′
1. Rise to Retro.	20+ 3=23	23 + 4=27	23	27	23	28
2. Retro.	20+ 0=20	20 − 4=16	20	16	20	16
3. Retro. to Set.	20 + 7+18=45	45 + 7=52	45	52	46	54
4. Set. to Rise	20+12=32	32 +26=58	32	58	33	56

[कुम्भः]

कुम्भे(ऽह्नां) विंशत्या [रूप]युतया 'हुतभुग्वेद'-'द्विदिननाथैः |
द्वाविंशतिरंशा पञ्च(दशा-ऽर्थार्थका) षष्टिः || ५२ ||

50a. A. धन्वि; B. धन्वनि. A.B. दिच साधाष्टौ (B. याष्टौ); C. दिवसार्थाष्टौ; D. दिवसानष्टिं षट्कृतिं षट्
b. A.B.C.D. षोडश (A. षोडस) for विंशं A.B.C.D. दशोनं. A. व for च
c. A1. ते स्फुः; A2.B. ते स्युः. A.B.C.D. शशिविषयोनाः (A.B. नौः)
d. A.B.C.D. सैकास्त्रिं (A. त्र्यं) शान्विता.

51a. A.B. द्युदशं.
b. A.B.C. मुनिहीनं; D. [मुनियुक्तं]
c. A.B.C.D. अंशा रूपेणोनाः
d. A.B.C.D. सैकैकाश्चोत्कृति

52. In Aquarius, the *gati*-s are:

	Degrees	Minutes	Textual °	′	Calculated °	′
1. Rise to Retro.	=20	22	20	22	20	22
2. Retro.	20 + 1=21	15	21	15	21	15
3. Retro. to Set.	=43	55	43	55	46	55
4. Set. to Rise.	2 × 12=24	60	25	00	27	51

[मीनः]

मीनेऽ[‘ष्टादश’]मह्नां ‘शशि’-‘विषय’-युता ‘हुताश’ [सागरकाः] |
‘त्र्यष्टकाः ‘कृति’ (‘विश्वं’ स्यात्) ‘शतार्धं’ मे‘कोनंमंशाः स्युः || ५३ ||

53. In Pisces, the *gati-s* are:

	Degrees	Minutes	Textual °	′	Calculated °	′
1. Rise to Retro.	18 + 1=19	20	19	20	19	19
2. Retro.	18 + 5=23	13	23	13	23	14
3. Retro. to Set.	43=43	50	43	50	43	52
4. Set. to Rise	3 × 8=24	49	24	49	24	47

[बुधगतीनां निर्णयः]

(अस्तो)दयान्तरांशा बुधस्य दिवसाश्चतुर्थ[या] गत्या |
उदयाद् वक्रं प्रथमा तृतीयगत्याऽऽनुवक्र(मस्तमयान्तम्) || ५४ ||

52a. A. कुंभेह्ना. A1. त्रिशत्या; D. त्रिकृत्या
b. A.B. दगतभुग्दिवेददिननाथैः; C.D. हुतमुग् द्विवेद (D. दिनेश) दिननाथैः
d. A.B.C. पञ्चवर्गमथाब्धिका षष्टिः (C. र्गमर्थाब्धिका): D. पञ्चवर्गं सुराधिपाः षष्टिः

53b. A.B.C.D. मीने त्र्यष्टकमह्नां
b. for सागरकाः, A1. संशरं; B1. शशीष्टं, B2. शासशिष्टं; B3. शशीरं; C.D. संयुक्तम्
c. A.B.C.D. त्र्यष्टककृतिविंशत्या (D. विंशत्याः;)
d. B2. शनार्थ. A.B. मष्टां स्युः

Specifications of the gati-s of Mercury

54. From setting to rising the degrees and days are given by the fourth *gati*. From rising to *vakra* (beginning) is (given by) the first *gati*. The third *gati* is (from) *anuvakra* (i.e., end of retrogression) to setting.

It will be seen that this verse explains what the four *gati*-s indicate a fact which has not been mentioned earlier. Actually, there is no direct reference to the second *gati*. But it can be inferred that this gives the retrogression period and the degrees.

TS have made some emendations but have not translated them but say that they are not able to comprehend the meaning of these verses. NP have adopted the emendations of TS and have just translated them as they are and that does not make any sense. They comment: "We cannot connect any rational procedure with the verses XVII, 54-56".

गतिविश्लेषकृतिघ्नैरंशैर्गतिवर्गभाजितैर्लब्धम् |
हित्वा राशिभ्यो भुक्तं प्रथमगतौ वक्रपश्चाच्च || ५५ ||
वक्रगतौ पूर्वार्धे तृतीयगत्यां च यत्कृतिं गुणितैः |
भागैर्गतकृतिभक्तैः फलमनुपाताच्चतुर्थगतौ || ५६ ||

55. By the square of the difference in *gati*-s (days) multiply the degrees and divide by the square of the *gati-s*. The result is to be subtracted from the degrees and that gives the degrees gone in the first *gati* and in the second half of *vakra-gati*.

56. In the first half of *vakra-gati* and in the third *gati* multiply the square (of the days passed) by the degrees and divide by the square of the *gati-s* (days). For the fourth *gati* the result is obtained by (direct) proportion [since the motion in this section is practically uniform.]

54a. A. अष्टो; C. अर्को; D. अथो. A.B.C. न्तरांशान्
b. A.B.C.D. दिवसाश्चतुर्थगत्या occurs as c. They have as b, बुधस्य कालांश (A.B. काल़ांश) कांस्त्रिगत्यूनान् (A.B. गत्यूनात्, D. गतीनाम्)
d. A.B.C.D. अनुवक्रमजमीनयोर्मन्दम् (A. योन्दम्, B. योर्मदम्).

55a. B. ०रंसैगत०
c. B. भुकं
d. A. गातौ. A. वक्रपश्चाद्वा; B. वक्रपश्चाच्व;. D. वक्रपश्चात्

56a. A. वर्गौक्रिगतौ; B. चक्रगतौ
b. A.C. गत्या च; D. गत्याश्च
A. यात्कृतं; B. तक्षत. C. गुणितम्; D. [यात्कृति गुणितैः]
c. A.B. गतिकृति (B. क्रति). B1. भत्यै; B2.3. भृत्यै
d. D. ०मनुपाश्च च. A.B. ०र्थभागगनौ (B2.3. गतौ)

[दृक्कर्म—आक्षम्]

ज्याविधिविक्षेपघ्ना (च्च) रकाला'दम्बराष्टवेदां'शम् |
जह्यात् क्षिपेच्च याम्योत्त (रे) ग्रहे स्वं यथा (काष्ठम्) || ५७ ||
एवं कृते [ग्रहान्त] रांशकैरस्तदर्शनं तेषाम् |

Correction for mean elongation in heliacal rising

57. Find the R sine of the latitude of the body. Multiply the (maximum) half-*cara* (i.e. the half difference between the half day-time or night-time from 15 (*nāḍis*.) in *vināḍis*, by this R sine, and divide by 480. Add this or subtract this (to or from the Moon or star-planet) if the latitude is north or south, according to the proper direction, (i.e. according as the phenomenon of setting or rising, takes place in the west or east, respectively).

58a-b. When this is done, their setting or rising happens according to the interval in degrees (between the Sun, and the planet given in XVII.12, or the Moon).

Note 1. There is a lot of lacunae in verse 57. The half-*cara-vināḍis* meant is the maximum for the place. *yathākakṣam* is meaningless here and is corrected into *yathākāṣṭham*, i.e. according to the direction, but the direction is not mentioned. If north latitude, the addition is for the Moon or planet in the west. Also if north latitude, the subtraction from the Moon or star planet is to be done for the east. If south latitude, the subtraction is for the west, and the addition for the east. These things can be got by a little reflection.

Note 2. The amount of degrees to be applied can simply be got by multiplying the degrees of latitude of the body by the tangent of the latitude of the place. (The equinoctial mid-day shadow of the 12″ gnomon ÷ 12, is tan. latitude of a place). The amount got is very rough.

The degrees wanted = Sin. half *cara* (i.e., tan latitude of place x tan. declination of the Sun) × sin (90° – angle for heliacal rising), nearly. The last term is neglected here, tan declination is roughly taken as 48′, half-*cara* is converted into degrees by division by 10, and the conversion into sine-function is applied to the latitude of the planet instead of the half-*cara*, as roughly equal.

Note 3. This application is what is technically called *Ākṣa-dṛkkarma*. The *Āyana-dṛkkarma* is neglected.

Note 4. The heliacal rising of the Moon, and of Venus and Mercury when retrograde, takes place in the west. The heliacal setting of the Moon and retrograde Venus and retrograde Mercury takes place in the east. Otherwise, all star-planets set in the west and rise in the east. (This *Siddhānta* does not envisage the setting or rising of Venus and Mercury when retrograde, no separate degree for that being given).

57a. B1.3. ज्याविधिविधि
b. A.B. च for च्च A. °दंवराष्ट; B. चरकादि (B2. कालादि) चराष्टवेदांशं
c. A. जह्याक्षि. A. यान्मो
d. A. त्तरं; B. °तंर°. C. स्वे. D. [कक्ष्यम्]

58a-b. A.B.C.D. ग्रहार्कान्तरांशकैः B. °तिष्टतिथि°

चन्द्रादीनां 'द्वादश मनुरवितिथ्यष्टतिथि'संज्ञैः ॥ ५८ ॥

58c-d. The setting and rising (mentioned above in verse 58a) is by 12°, 14°, 12°, 15°, 8° and 15° for the Moon etc.

Note 1. This has to be taken with verse 58a. The degrees given here separately are according to the *Vāsiṣtha-Pauliśa*, which do not instruct the correction due to the latitude of the planet or for even the latitude of place (*ākṣa-valana*). The result will therefore be very rough.

Note 2. These degrees are necessarily arbitrary as mentioned already, and the correctness of the numbers cannot be verified in the absence of the original *siddhāntas* which are now lost. But we can guess the probable values as we are sure of the relative luminosities of the planets. The numbers seem to have been misplaced. They should be *dvādaśa, tithi, manu, ravi, aṣṭa, tithi* (12°, 15°, 14°, 12°, 8°, 15° for Moon etc.) All *siddhañtas* give 17° for Mars instead of 15°. The rest are nearly correctly given, according to one *siddhānta* or other.

[कालभागानां क्षेत्रभागकरणम्]

(त्रि)शतविनाडीगुणितै(रू)द(य) [वि]नाडीप्रमाणहृतैः ।
लब्धांशकप्रमाणादुदयोऽस्तं वा स्फुटं वाच्यम् ॥ ५९ ॥

Conversion of time-degrees into distance-degrees

59. Multiply the degrees by 300 and divide by the *vināḍis* of oblique ascensional difference of the sign, rising at that moment, (near sunset or sunrise, as the case may be), and get the respective degrees. When the distance between the sun and planet is that much, the respective setting or rising takes place.

Note 1. This work is what is known as the conversion of time-degrees (*kālabhāga*) into degrees of distance on the ecliptic (*kṣetrabhāga*). Since the rule has to apply commonly to *Saura* on the one hand and the *Vāsiṣtha-Paulīśa* on the other, it has been placed last.

Note 2. Since the positions of the Sun, Moon and planets are given only on the ecliptic, this conversion is necessary to measure distances.

ज्ञसिताऽऽरेज्या (र्क्यू)नाः शशिनः प्रत्युत्तरं खरां (शुश्च) ।
ज्ञात्वैवं विक्षेपादादेशमनागतं कुर्यात् ॥ ६० ॥

60. (The rising takes place in the east when) Mercury, Venus, Mars, Jupiter and Saturn are less in longitude than the Sun, and the Sun is less than the Moon in the opposite direction, (i.e., west). Making the computation according to the instruction given above using the latitude etc, the phenomenon should be predicted.

59a. A. त्रिशत; B. त्रिंशति. B. विनाडी
b. A. घदशनाडी; B. श्चदशनाडीं

60a. A.B.C. रज्यार्कोना:
b. A.B. खरांशोना; C. खगांशेन; D. [ख्यंशाश्च]
d. B. मनागमतत्

Note. The verse is very corrupt. But knowing what it is about we can give the meaning, making possible corrections. The rising is mentioned here as it is more important for application to *dharmaśāstra* etc. But rising also envisages setting with the word 'less' taken for 'more', and 'more' for 'less'.

Example 1. The latitude of the moon is 3° 45′ N. The maximum half-cara of the place is 150 vināḍis. The oblique ascensional difference of the rising sign is 280 vināḍis near sunset. Find the ecliptic distance between the Sun and Moon, for the heliacal rising of the Moon.

The time-degrees for the moon is 12°. The heliacal rising of the Moon takes place in the evening. $R \sin 3° 45' \times 150 \div 480 = 7\ 38/60 \times 150 \div 480 = 2° 23'$.

This is additive since the Moon's latitude is north, and the phenomena pertains to the west. Therefore, the corrected time-degrees = 14°.

$14° \times 300 \div 280 = 15°$ is the distance on the ecliptic between the Sun and the Moon, required.

Example 2. For the same place, (i.e., max. half-cara 150 vināḍis) find the ecliptic distance required for heliacal rising, given: the latitude of Mars 1° 15′ N, and the oblique ascensional difference near sunrise at that time is 330 vināḍis.

The latitude correction to the time degrees (17° for Mars) = $R \sin 1° 15' \times 150 \div 480 = 2' 33'' \times 150 \div 480$ taken as degrees = 48′.

As the latitude is north, and the phenomenon pertains to the east, (since it is the rising of Mars that is considered), it is subtractive.

$\therefore 17° - 48' = 16° 12'$ is the corrected time-degrees. $16° 12' \times 300 \div 330 = 14° 44'$, is the distance on the ecliptic required.

[पञ्चसिद्धान्तिकोपसंहारः]

आवन्त्यकः समासा(च्छि)ष्यहितार्थं स्फुटाङ्कसमम् |
चक्रे वराहमिहिरः ताराग्रहकारिकातंत्रम् || ६१ ||

प्रद्युम्नभूमितनये जी(वे) (सौरेऽथ वि)जयनन्दिकृते |
बुधे (च भग्नो) [त्साहः] स्फुटमिदं करणं भजतात् || ६२ ||

दृष्टं वराहमिहिरेण सुखप्रबोधं
....
....
.... || ६३ ||

61. For the good of his disciples, Varāhamihira, belonging to the Avanti country (Ujjain region), wrote this section dealing with the star-planets, briefly but with the constants agreeing with the original (*siddhāntas*).

62. A learner, discouraged by the computation of Mars by the astronomer Pradyumna, the computation of Jupiter according to the *Saura siddhānta*, and

the computation of Mercury by Vijayanandi, can have recourse to this section of the manual.

63. By Varāhamihira has been seen, (i.e., written) (*this karaṇa*) easy to understand,....................

Note 1. Verses 61 and 62 clearly close the section dealing with the star-planets. Since VM says that he has improved on the earlier authors, he must be referring to Chapter XVI and XVII, dealing with the *Saura.* His reference to his improvement on the *Saura* itself in the case of Jupiter must refer to the *bīja* correction made by him in XVI. Indeed, his dissatisfaction with the Jupiter of the *Saura* is reflected in his formula for computing Jupiter to give the years of the sixty-year Jovian cycle, given in his *Bṛhatsamhitā*, in the chapter dealing with the motion of Bṛhaspati (Jupiter). As for chap. XVIII, he could not have meant the *Vāsiṣṭha-Pauliśa* star-planets there as an improvement, they being crude.

Note 2. Verse 63 evidently closes the *Pāncasiddhāntikā*, as indicated by the *Vasantatilakā* metre of the verse instead of the regular *āryā* metre. But unfortunately the last three feet are missing. Perhaps it is a purposely done 'black-out' by a later astronomer-scribe, to add his spurious verses 64-81 in continuation (see below) and, unfortunately, only his manuscript has survived as the archetype of the few extant manuscripts.

61a. B. आयंतकः समासाः
b. A. छिष्पहि॰; B. छिसंध्यं हि॰; B2.3. छिसंष्यं हि॰
A.B. ॰र्थं तमद्गस्फु॰; C. र्थं [ततः] स्फु॰;
D. ॰थं [वियद्गस्फुटांशम्]
c. A.B. मिहरः

62a. A. प्रद्यम्र. B. भुमि
b. A.B. जीवै (B3. जीवे)
A. शौरयवावीजय॰; B. सौरि यवविजयं
D. सौरेऽथवा विजय॰
c-d. A. बुधे वनग्नास्फुट; B. छुधे च मग्रास्फुटं; D. बुधो भग्नः स्फुटमिदं करणं भजति दृष्टं वराहमिहिरेण || ६२ ||
d. C. प्रस्फुटमिदं, om. करणं. A.B. भजतां;
D. drops the word.

63a. A.B.C. मिहरेण. B. प्रबोधां
b-d. A.B.C. gap indicated for the three quarters of the verse.
D. Ignores the expression सुखप्रबोधं in this verse and constitutes a new half verse for the previous verse. as: बुधो भग्नः स्फुटमिदं करणं भजति दृष्टं वराहमिहिरेण || In consequence, the numbering of verses than in A is one less in D, hereforward.

[इति पञ्चसिद्धान्तिाकायां वराहमिहिरविरचितायां ग्रहोदयास्तो नाम अष्टादशोऽध्यायः]

Thus ends Chapter Eighteen entitled '(Vāsiṣṭha-) Pauliśa-Siddhānta – Rising and Setting of Planets', in the Pañcasiddhāntikā composed by Varāhamihira

Chapter Eighteen 64-81 (A Spurious Supplement)

Computation of the Star-Planets in brief

[पञ्चसिद्धान्तिकायां प्रक्षेपः — ताराग्रहाः]

Spuriousness of this Section

That verses 64-81 of *Pāncasiddhāntikā* form only an appendage to a manuscript of the work and not a composition of Varāhamihira, is evident from its occurring after the work has closed in the customary way with a concluding colophonic verse, with its metre changed to *Vàsantatilakā* from the *āryā* metre in which all the previous verses of the chapter had been couched, and with the author speaking about himself in this concluding verse. It is also to be noted that the set of verse 64 to 81 begin with a new salutation. Had these verses really belonged to the *PS*, the customary colophonic verse must have come at their end, and significantly there is no such colophonic verses at the end. Further, in verse 65 it is said that the author considers this as a superior set containing a previous method or matter and that he was giving it out, with a liberal mind, to the generality of astronomers without hiding it from them. But actually it is inferior stuff, and can give only very rough results since the equation of the centre is dispensed with, only the equation of conjunction being given, which makes it valueless. The author boasts here that he has made things easy, and takes credit for this which only a novice could have done. Fancy VM speaking thus, when in verse 62 he is so intent on accuracy that he says, "Let people who have been dissatisfied with the inaccuracy of astronomers like Pradyumna, Vijayanandi etc., have recourse to his treatment of the *Saura*." Further, there are mistakes in the computation of Venus and Mercury, unpardonable in any astronomer. (See below, Note 2 under verses 70-72). The above-mentioned aspects of verses 64-81 have escaped the notice both of TS and NP, who both take them as genuine compositions of VM. Moreover, NP obliterate verse 63, the concluding genuine verse of *PS*, by not including it in their text, though a few words thereof are present in all the manuscripts of the work and in some of the manuscripts it bears a serial number; thus, verses 64 to 81 are numbered in NP as 63 to 80.

These spurious verses are dealt with below for the sake of completeness of the text as found in the parent manuscript of the *PS* from which all its manuscripts available now have been derived.

[उपक्रमः]

प्रस्तावेऽपि न दोषा[न्] जान(न्न)पि न वक्ति यः परोक्षस्य |
प्रथयति गु(णां) श्च तस्मै सुजनाय न(मः) परहिताय || ६४ ||

अष्टादशभिर्बद्धान्या ताराग्रहतंत्रमेतदार्याभिः |
(वरमिति) वराहमिहिरो ददाति निर्मत्सरः करुणाम् || ६५ ||

Salutation

64. Salutation to the good people, ever interested in the welfare of others, who even when knowing the faults of others, and even when there is an opportunity, do not mention their faults, but proclaim their good qualities.

65. In eighteen *āryā* verses, Varāhamihira, without feeling any jealousy, gives this manual to the world, ending with the treatment of the planets, thinking that it is good.

Note 1. The emendations are TS's also.

Note 2. Verse 64 is a paranomasia and means also, "Salutation to the good science of astronomy called technically *parahita-gaṇita* (prevalent in Kerala in South India), which at the beginning deals only with mean motions, though knowing its defective nature as not being true motions, and which furnishes tabular values of equations going by the means, *mandajyā* (R sine table of the equation of the centre), *karkijyā* (R sine table of the equation of conjunction for the anomaly 90° to 270°) and *makarajyā* (R sine table of the equation of conjunction for the anomaly 270° to 90°)."

This meaning being not obvious to the ordinary reader, I give the phrase by phrase meaning:

prastāve (granthārambhe), parokṣasya (asphuṭagrahasya) doṣān (asphuṭatvādi-doṣān) jānann api yaḥ na vakti (jānann api na vadati, madhyagater eva prakṛtatvāt) guṇān (mandajyā, karkijyā, makarajyā ityādi-guṇaśabda-vācyā jyāḥ) prathayati (prakaṭīkaroti, gaṇayitvā likhatītī yāvat), tasmai sujanāya (tasmai śobhanajanmane) parahitāya (parahitagaṇitāya) namaḥ (namo 'stu).

Note 3. These two verses also form part of the 18 verses mentioned. So, actually there are only 16 verses (66 to 81), giving the computation.

[सौरदिनम्]

आकरणाद् रविभागा दिवसा(श्चा)रांशका रवौ कार्याः ।
अधिका (य)दा दि(ने)भ्यो भागा ज्ञेयास्तदा चक्रात् ॥ ६६ ॥

'Sun's day' (Sauradina)

66. From the epoch, to the time of computation of the planet, find the Sun's degrees passed. These are to be technically called 'days', (and used in the computation). Find the remainder after dividing by the cycle number given for the respective star-planet. Take the 'days' of motion corresponding to the set of motions given to the respective planet. These are degrees of planetary motion. Add this to the Sun's longitude. The true planet is got.

Note 1. The 'days' mentioned here is only what is called *sauradina* ('Sun's day') as distinguished from the *sāvana* or civil day, and are actually degrees. (This is like the word 'light-year', which is used as a unit of distance). This instruction is given with respect to all planets.

64a. A.B.दोषाः
b. A.जानन्नापि न; B.जानानापि (B.जुना॰).
A.घटोक्षस्य
c. B.प्रथयाति. A.गुणाश्च तस्मै; B.गुणास्तस्मै
d. A.सुजनयानमपर; B.सुजनया तमः. B.परिहिताया

65a. A.॰र्वद्धा; B.॰र्वधा
b. B.दायाभिः
c. A.वराहमिह वराहमिहिरो (A2.॰मितिहरो);
B.मिहरवराहमिहरो; C.॰मिहरो
d. B.निमत्सरः

66b. A.दिवमाश्चरांशका; B.दिवसाश्चंशका
B.कार्या
c. A.॰कार्यदा दितेभ्यो; B.॰कार्यदा दिनेभ्यो
d. A.B.वक्रात्

Note 2. The cycle given for each planet is only the period of the planet's synodic revolution converted into the solar days, i.e., it is the synodic period × 360° ÷ 365-15-30, nearly. When so converted, we have:

	Mercury	Venus	Mars	Jup.	Saturn
The regular synodic days:	115-52-45	583-55	779-57	398-53	378-6
Converted into solar days:	114 6/29	575½	768-45	393 1/7	372 2/3

The second set is given for the respective planet, saying that the synodic period is so many 'days'. Not knowing this TS have remarked that they do not understand why there is so much difference in the periods from the regular days generally known. Also, they say they cannot dismiss them as wrong, since the numbers given are checked in the computation itself. (See pages lx*iii*-lx*iv* of Introduction in TS's edition).

NP have understood that the cycles are in solar 'days'. But, they have remarked that 'VM' has confused the days and degrees, not realising that there is a purpose in giving the cycles in the solar day units. These units have been used because, now, the 'days' and the 'degrees' will have the same meaning, and they can be combined without, at every point, instructing it. Thus, ultimately, the combined value is the degrees of the true planet.

Example 1. Days from epoch 1,20,553. Find the 'days', and assuming the Sun at epoch as zero, find the Sun at the end of 1,20,553 days.

1,20,553 × 360 ÷ 365-15-30 = 1,18,187.5 'days'.

This plus zero, and divided out by 360° = 17°.5, Sun's longitude.

[कुजस्फुटः]

'नवयम(गुणर्तु'हीने) 'कृता'(ह)ते 'विषयसप्तखाग्नि'हते |
भूयो (हृ)ते चतुर्भिः [निरंश]दिवसा महीजस्य || ६७ ||
'षड् (विषयै)''स्ति(थ्यू)'नः दृष्टो'वसुधृति'[भि]-रंशकाः (ष)ष्टिः
अष्टशतेन(च)षष्टिः सप्तत्या (त्र्य)धिकया नवतिः || ६८ ||
षष्ट्याष्टयुक्तया (श)तदलं च 'खाश्वि द्विकै': 'स्वराद्रि'(घ्नाः) |
अस्तमितोऽतः सप्ताष्टकेन तिथयो' निरंशग(गतिः) || ६९ ||
|| कुजः ||

Motion of Mars

67. Subtract 6329 from the 'days'. Multiply the remainder by 4 and divide out by 3075. Take the remainder and divide by 4. These are the 'days' after conjunction (i.e., the anomaly of conj.) for Mars.

68-69. After 56 'days' it goes behind the Sun by 15°, and becomes observable, (i.e., the heliacal setting ends). In 188, 108, 73, 68, 220, 'days' Mars lags behind by 60°, 60°, 90°, 50°, 70°, respectively. Then it sets heliacally, and in 56 'days' lags 15° behind and goes into conjunction.

Note 1. I generally agree with TS's emendations. But in verse 68, I give *ṣaḍviṣayaih* for *ṣaḍtriṃśat-savaiḥ*, which latter is both meaningless and has one *mātrā* extra. TS's *ṣaḍvargaiḥ* does not agree with the last *saptāṣṭakena*, for the numbers should agree or at least nearly agree. *saptatyā dvyadhikayā* has been emended by me into *saptatyā tradhikayā*, and *khābdhi* into *khāśvi*. These will not only make the total correct, but also bring about agreement with the *Siddhāntas*, which all generally agree with the actual as given by modern astronomy.

	1	2	3	4	5	6	7	Total
Degrees moving behind	− 15° *asta..*	− 60°	− 60°	− 90° *vakra*	− 50°	− 70°	− 15° *asta.*	− 360°
'Days' given	56	188	108	73	68	220	56	769
Actual 'days'	54	188	106	72	75	220	54	769

The great difference in 'days' between the 68 given and 75 actual must be explained by their following next to the retrograde period, where even a large number of days can produce a very small difference in degrees. So, correction to whole degrees can produce this difference in days.

Note 2. Verse 67 means that 6329 'days' after epoch, there is conjunction, which repeats after each synodic cycle. The cycle for Mars is 768¾ 'days'. So instead of dividing by 768¾, we are asked to multiply by 4 and divide by 3075. To get back the true remainder, the remainder here is divided by 4.

Note 3. The following points deserve to be noted:

(a) In the case of all star-planets the total 'days' should be equal to the days of the respective cycle.

(b) In the case of the superior planets, viz. Mars, Jupiter and Saturn, the degrees are all negative and add upto − 360°. When the given degrees is numerically greater than the corresponding 'days', (for e.g., − 90° for 73 'days' here) the planet is retrograde.

(c) The heliacal setting and rising are at the beginning and end of the cycle for all. But, for the two inferior planets, viz. Mercury and Venus, there is another setting and rising at inferior conjunction when the two are retrograde.

67a. A. गुणार्नुहीना; B. तमयम गुणार्तुहीना
b. A. कृताहते; B. क्रुताहते. B. द्विषाय.
B. सप्तखग्नि
c. A.B. भूयो हतो. B. चतुर्भि
d. A. विरंसदि॰; B. चिरंस दि॰;. B3. महीजस्या
68a. A. षट्त्रित्सवैस्तिथ्यूनो; B. षड्विवैस्तिथ्यतो;
C. षड्वगैस्तिथ्यूनो; D. षट्त्रिशैस्तिथ्यंशा
b. B. दुष्टो. A.B. धृतिरंशकाच्छष्टिः (B. ॰का षष्टिः)
c. A. शते न व षष्ठिः
d. A.B. द्व्यधिकाया
69a. A. षृट्योष्ट; B. षष्टोष्ट
a-b. A. संतदलं; B. सप्तदलं
b. A.B.C.D. खाब्धिद्विकैः (B. ॰धिकैः)
A.B1.2. स्वरादिघ्राः; C.D. स्वरा दिग्घ्राः
c. B3. अस्तामितो
c-d. B. साष्टकेन
d. A.B. निरंगशनिः; C.D. निरंशगतिः

(d) The rising and setting are given by observation at different regions and different conditions of the atmosphere, and therefore vary among the *siddhāntas*.

(e) In the case of the inferior planets the degrees should add upto zero. When the degrees are positive and greater than the days, the planet is gaining upon the Sun, and the total gain is its elongation. When the degrees are less than the 'days', the planet is lagging behind. When the degrees are negative and numerically greater than the 'days', the planet is retrograde and comes at the middle of the cycle, if the cycle begins and ends at superior conjunction.

Example 2. Compute Mars at 1,20,553 days from epoch.

The solar days are, 1,20,553 × 360 ÷ 365-15-30 = 1,18,817.5, and the Sun is 17°.5, taking the sun at epoch as zero, which it nearly is as already shown.

1,18,817.5 − 6329 = 1,12,488.5
1,12,488.5 × 4 ÷ 3075 leaves the remainder 1004.
1004 ÷ 4 = 251, real remainder of 'days'.

During this period we get the movement: − 15° in 56 'days', − 60° in 188 'days', and − 4° for the 7 'days' remaining, total − 79°.

Adding − 79° to the Sun, 17°.5, True Mars = 298.5°.

[बुधस्फुटः]

वि'शशिवसुरसे(न्द्रे)' 'नव(यम)'गुणिते'ऽर्करा[म]गुण'भक्ते |
गुणकारहृते लब्धान्यहानि शीतांशुपुत्रस्य || ७० ||
दशभिर्द्वादशही(नः) प्रागुदितो 'म(नु)'भिरून'(नन्दां'शाः) |
'धृति'भिः(स)नवोऽस्तमितः त्रिंशद्भिरुदेति स'(शराश्विः)' || ७१ ||
अष्टाद(श)भिः(स)नवः षोडशभिश्चा(र्क)वर्जितोऽस्तमितः |
पश्चा'द्वसु'भिर्नववर्जितो निरं(शं) बुधो याति || ७२ ||
|| बुधः ||

Motion of Mercury

70. Subtract 14,681 from the 'days'. Multiply the remainder by 29, and divide out by 3312. Take the remainder and divide by 29. The 'days' for Mercury in the cycle is got.

70a. A.विंशशि. A.B.रसेंद्रा; D. [रसेन्दौ]
b. A.B.1.2.नवनवगुणिते. A.B.1.2.॰रागुणभक्ते
c. A.B.हते
c-d. B1.2.॰ब्धान्य-gap-तांशु॰;
B3.॰ब्धुनाशि-gap-तांशु॰

71a. A.दशभिद्वा॰. A.B.हीनाः
b. A.मनिभिरूनभश्चांशाः; B.र्मनाभीरूनत्तश्चांशाः;
C.मनु[भिरूनिताश्चाशाः]; D.मनु [भिर्विषयश्चांशाः]
c. A.शनवो; B.॰भिः-gap-नवो; D. [॰भिर्मनवो]॰
d. A.॰रुदेति. A.B.सरसाश्चः (B.श्वाः);
C. [सरसांशः]; D. [स रसांशाः]

71. In 10 'days' Mercury falls back by 12°, and rises in the east. In 14 'days' more it lags by 9°. Then in 18 'days' it gains 9°. Then it sets, and in 30 'days' gains 25° and rises heliacally.

72. Then in 18 'days' it gains 9°. In 16 'days' it lags 12°, and sets in the west. Then in 8 'days' it lags 9°, and gets into conjunction.

Note 1. In verses 71 and 72 my corrections are based on the need to conform as nearly as possible to reality, and they are also, as far as possible, kept close to the text. *śarāsviḥ*, 25, may also be *jalāśviḥ*, 24. The values are:

	1	2	3	4	5	6	7	Total
Given degrees	− 12°	− 9°	+ 9°	+ 25° (? + 24)	+ 9°	− 12°	− 9°	0°
	vakrāsta	*vakra*		*asta*		*vakra*	*vakrāsta*	
Given 'days'	10	14	18	30	18	16	8	114
Correct 'days'	8	16	18	30 (?28)	18	18	6(?8)	114

In columns 6 and 7 it should be − 9° and − 12°, or atleast − 10° − 11° though the text letters are unmistakable.

Note 2. The constant for subtraction, 14,681 shows that the planet is in superior conjunction, since the epoch position of the planet must agree with that given by modern astronomy and other *siddhāntas*, atleast within a few degrees. (See table appended). If so, the Table of cycle motions given should begin and close with superior conjunction. But in the Table given, the cycle begins and closes with the inferior conj. as can be seen from the retrograde motion with which the Table begins and ends, and the most rapid motion (*aticāra*) coming at the middle.

The astronomer of very inferior calibre who has made this interpolation, has been misled by the two sets of heliacal rising and setting in the case of the inferior planets, Mercury and Venus. He has wanted to begin the motions with the rising in the east and setting in the west, to fall in line with others, not realising that this occurs during its retrograde motion which falls at inferior conjunction coming in the middle. This is another proof that VM cannot be the author of this set of dealing with the star-planets. (This author has committed the same mistake in the similar case of Venus, where the mistake can be seen glaringly when the true Venus got is compared with that of the other *siddhāntas* or modern astronomy). If he does want to begin with rising in the east and end with setting in the west, he must begin and end his cycle table with the inferior conj. and to this he must add to the days to be subtracted half the cycle days, equal to 57 3/29 days. (The cycle days = 3312 ÷ 29 = 114 6/29).

72a. A. अष्टादभिः नव; B. अष्टादशभिः नवः;
D. अष्टादशभिर्मनवः
b. A.B.C.D. षोडशभिश्चाष्टवर्जितो
d. A. निरंस; B. निरंश. A.C.D. बुधोपि याति

[गुरुस्फुटः]

रहिते 'द्वियमशरा[ष्ट्यां] '(नगा)'हते 'द्विविषय(स्व)राश्वि'हते |
सप्तहृते देवगु(रोः) भवन्ति दिवसा [निरंशस्य] || ७३ ||
सर्वे(ऽर्का)त् संशोध्याः षोडशभिर्द्वादशोदितः प्रा(च्याम्) |
'कृतविषयैः' 'कृतवेदाः' सप्तत्या 'सार्णवाः षष्टिः' ||७४ ||
'नवदिग्भिः' 'शून्यार्काः' '[सा]ष्टाशीत्या' 'रसस्वरा'[श्चैव] |
'शून्यकृ(तै)'र्द्वात्रिंशत् (ततोऽस्तगः) षोडशभि'रर्काः)' || ७५ ||
|| जीवः ||

Motion of Jupiter

73. Deduct 16,552 from the 'days'. Multiply the remainder by 7 and divide by 2752. Divide the remainder here by 7. The 'days' from conjunction are got.

74-75. All degrees given are to be subtracted from the sun. In 16 'days' it moves 12° and rises in the east. Then in 54, 70, 49, 88, 40 days it moves 44°, 64°, 120°, 76°, 32°. Then it sets in the west, moves 12° in 16 days and joins the Sun.

Note 1. The first foot of verse 73 is faulty containing 3 *mātrās* extra, and corrupt. So it has been corrected. The rest of verses 73 and 74 are TS's emendations. In 75, all emendations are TS's, excepting those for grammar.

Note 2. The cycle is 2752 ÷ 7 = 393 1/7 days. The days and degrees are:

	1	2	3	4	5	6	7	Total
Degrees	– 12° *asta*	– 44°	– 64°	– 120° *vakra*	– 76°	– 32°	– 12° *asta*	– 360°
Given days	16	54	70	109	88	40	16	393
Near correct 'days'	16	·54	70	109	88	40	16	393

73a. A.B.C.रहितेऽष्टद्वि°; D.रहिते यम°
A.B.C.D.शराष्टिभिः
b. A.नाग. B.हिते A.विषयस्व (A2.श्व)
राश्विहृ (A1.हृ) ते; B.विषयंश्चराश्विहृते
c. A.B.गुरौ
d. A.तिरांसंगम्याः; B.निरंशगम्याः; C. [निरंशेभ्यः]
D. [निरंशगस्य]

74a. A.सर्वेकात्; B.सर्वेकान्
b. A.प्राक्र
c. B. Hapl. om. of कृतविषयैः
d. C.D.सार्णवा षष्टिः

75a. B.नवा दिग्भिः
a-b. A.B.C.D.शून्यार्काष्टाशीत्या (B.°र्कष्टा°)
b. A.B.C.स्वराद्याभिः; D.स्वरा द्युभिः
c. A.B.°कृतिर्द्वा°
d. A.B.°तोतु (A2.नु; B1.2.रु)
A.मस्तगा (B1.2.गात्; B3.शा)
A.°शभिरर्कात्; B.°शाभिरर्का;
C.D.°शभिरर्कान्

[शुक्रस्फुटः]

'नयनार्क[धृतीन्दू]'ने द्विगुणे (रू)पेन्द्रि[येश्व]रै' र्भक्ते |
शे(षं) यत्त(द्द)लितं भृगुतनयनिरंशदिवसाः स्युः || ७६ ||
'विषयै'र्नवकविहीनः प्रागुदित'स्तिथि' [भि] 'रेक(य)म'हीनः |
'वसुकृत्या' 'ति(थ्यूनः)' 'कृताष्टिभिः' स(पञ्चकास्त्रिंशत्) || ७७ ||
(पञ्चा) [ष्ट]केन सद(शः) निरं[शगो]ऽतो विलोमगः पश्चात् |
उ(दे)ति (नि)रंशका(ले) (प्रया)ति (चा)स्तं वि(लोम)गतिः || ७८ ||
|| शुक्रः ||

Motion of Venus

76. Deduct 1,18,122 from the 'days'. Multiply by 2 and divide by 1151. Take the remainder and divide by 2. We have the 'days' from the conjunction of Venus.

77-78. In 5 'days' Venus lags by 9°, and rises in the east. In 15 days it lags 21°. In 64 days it lags 15°. In 164 days it gains by 35°. Then it sets in the east. Then in 40 days it gains 10°, and joins the Sun. Then, moving in accordance with the reversed order of the days for cycles given, it rises, after the days given from setting to conjunction (*i.e.*, 40 days), in the west, and moves till it reaches the setting in retrograde (and getting into the inferior conjunction) section.

Note 1. I have corrected *mitīndu* into *dhṛtīndu* for agreement with the Sun in superior conjunction which alone fits. TS's correction (also NP's) *mahīndu* does not bring agreement with the Sun either at superior conj. or inferior conj. There can be another possible correction *matīndu* (*mati* is 8). In the 64 days, flanking the retrograde, the days may be a little more or less, since a small error of observation can produce a difference of a large number of days. The lacunae is filled by me with *sapañcakāstriṃśat*, meaning 35°, to fit the number of degrees wanted to make up the total zero, and fitting the number of days given. TS's emendation, *kṛtāṣṭabhiḥ* will be far from fitting the total.

76a. A.B.॰र्कमितिदुने; C.D.॰र्कमहीन्दूने
b. A.B.रूपेन्द्रियैः स्वरै र्भ (B2.भ) क्ते
c. A1.शेषः. A1.यत्तदलितं; B.यकृदिलितं
d. B.॰वसा स्युः

77a. B3.नवका
b. A.B.तिथिरेकपम (B.यम) हीनः
c. A.तिथ्युन
d. A.B.॰ष्टिभिः स, rest of verse missing:
D.नः कृत (ष्नै] स्त्रिभिः स
C.॰भिः [सेषुरस्तगतः]; D.॰भिः [सपञ्चास्तगः]

78a. A.B.C.ष (B.स) ष्टाष्टकेन सदश (B.सदृश);
D.षष्टाष्टकेन स दश
b. A.निरंसतोतो; B.निरंशतातो
c. A.उदयति तिथिनिरंशकालो;
B.उदयतिथिनिरंशकालो
c-d. C.उदयति निरंशकालेन, याति;
D.उदयति निरंशकालात्र याति
d. A.B.नयति (B.भवति) वास्तं
A.B.विनाथगतिः; D.[दिनानाथ]गतिः

Moreover, their filling the lacuna by *seṣuḥ*, meaning 5° is quite inadequate to make up zero. I have emended *saṣṭāṣṭakena* into *pañcāṣṭakena*, meaning 5 × 8 = 40, which will fit the number of days. Also, 10° synodic motion there requires 40 days and it is also the period from setting to going into superior conjunction. *ṣaṣṭa* is patently wrong spelling, and *ṣaṣṭāṣṭakena* is meaningless. But TS and NP keep it, which is wrong. That this is the segment of heliacal setting to conj. can be inferred from *udayati* given for the next segment, and 10° for heliacal setting and rising at superior conj. is given by many *siddhāntas*. The other minor emendations are TS's.

Note 2. 1,18,122 seems to be a very large subtractive constant, equal to more than 300 years, while all others are very near VM's time. But I cannot think of any other number to fit.

Note 3. The maximum elongation is seen to be 45°, correctly. (Cf. Table).

	1	2	3	4	5	6	7	8	9	10	Total
Degrees passed	− 9° *vakrāsta*	− 21° *vakra*	− 15°	+ 35°	+ 10° *asta*	+ 10° *asta*	+ 35°	− 15°	− 21° *asta*	− 9° *vakrāsta*	0
Given days	5	15	64	164	40	40	164	64	15	5	576
Correct days	5	15	64	164	40	40	164	64	15	5	576

Note 4. The remark about Mercury, that the cycles begin and end with the superior conjunction according to the subtractive constant given, but the motions in the cycles begin and end with the inferior conjunction, holds in the case of Venus also, showing thereby that the author is an ignorant imposter, and cannot be VM. To correct the fault, 287¾ 'days' should be added or subtracted from the subtractive constant.

Example 3. Compute Venus at 1,20,553 days from epoch.

If the subtractive constant given in the text is used, 1,18,817.5 (already found in the example in Mars) − 1,18,122 = 695.5.

This × 2 ÷ 1151 leaves the remainder 240.

This divided by 2 gives 120 'days' gone in the cycle. We have for the first 5 days − 9°, and the next 15 days − 21° and the next 64 days − 15° and the remaining 36 days, 36 × 35 ÷ 164 = 7° 40′, totally − 37° 20′. Adding the Sun 17°.5 already found in the example for Mars, the true longitude of Venus is − 20°, i.e. 340°. (The example in the *Saurasiddhānta* for the same date has given 46°.)

The error in Venus, in using this method here, is 66°. On the other hand, let us use the cycle order re-arranged to begin from superior conjunction. It is 10° for 40 days, 35° for 164 days etc. We have 10° for 40 days, and for the remaining 80 days, 80 × 35 ÷ 164 = 17°, total 27°. Adding the Sun, 17°.5, we have, true Venus, 44°.5. This is close to the correct 46°. This exposes the ignorance of the imposter.

[शनिस्फुटः]

वि'धृतिशररसशशाङ्के' त्रिघ्ने 'धृतिरुद्र'भाजिते'ऽग्नि'हृते ।
सौर(स्य) 'धृति'(भि)'र(ष्टिः)' सार्धा (च) हानिरुदितः प्राक् ॥ ७९ ॥

अष्टनव(त्या) नवतिर्दलं च 'मनु'भिस्त्रयोदशविहीनाः |
'गुणरुद्रै': 'शून्यार्का' द्व्यूनेन शतेन 'शशिनवकम्' || ८० ||
अति जग[त्या सार्धा]र्का(न)स्तमे(त्य)तो 'नव(कु)भि' (र्नि)रंशम् |
षोडश सार्धा(न् सौ)रश्चरति रवेः सर्वदा हीनः || ८१ ||

|| शनैश्चरः ||

Motion of Saturn

79. Subtract 16,518 from the 'days', multiply by 3 and divide by 1118. Take the remainder here and divide by 3. The days left over in the cycle are got. In 18 days Saturn lags behind by 16½°, and rises in the east.

80-81. In 98, 14, 113, 98, and 13 'days', it falls behind 90½°, 13°, 120°, 91°, and 12½°, respectively. Then Saturn sets in the west, and joins the Sun passing 16½° in 19 days.

Note 1. In verse 79, *ṣaṭkavarka* is patently extra, forming syllables not required for the foot, and has been deleted by me as also by TS. *aṣṭābhiḥ* is corrected into *aṣṭiḥ* by me, as also by TS, to conform to grammar and facts. In the rest of the minor corrections there is no difference between our corrections.

In verse 80, I have retained the *dvi* in *dvyūnena*, while TS have made it *dyu*, meaning one day, which is not necessary, and which leads into trouble later, needing further correction. The minor corrections are common to both. In 81, I have filled up the lacuna by (*tyā sārdha*), while TS have made it (*tibhirardhā*). The word is *atijagatī*, and not *atijagatiḥ*, which alone can justify TS's *tibhiḥ*. Also, only *sārdhārka* can mean 12½, but their *ardhārka* can mean only 6. I have corrected *navati* into *navaku* keeping the *nava*. But TS have corrected it into *atidhṛti*, making unnecessary changes in the lettering, though both of us mean the same. The rest of the corrections are minor, and are acceptable.

79a. A.B.C.॰रसषट्कवर्क (B.वक्रे) शशाङ्के
b. B.भाजिताग्नि (B3.ग्नि)
c. A.सौरस्प. A.B.धृतिभिरष्टाभि (B1.2.भिः)
d. A.C.सार्धार्क; B.साद्धर्कि; D.सार्धार्काद्

80a. A.नवतिर्ज्या नवति॰; C.D.नवतिर्नवतिः
b. A1. B.C.D.विहीनः
c. B2.शून्यर्का
d. C.D. [द्यूनेन]; Ms. A2. breaks off here.
A1.शाशि

81a. A1.जग---र्का
a-b. A.1.3.॰र्कारस्त (B.स्ते) मेत्यंतो (B3.मेसंतो);
C.॰रर्द्धार्कानस्तमेत्यतो; D. [॰रर्कान् सार्धानस्तमेति]
b. A1.B.नवतिभिर्विरंशं;
C.ऽतिधृतिर्निरंशम्; D.नव [दश] भिर्निरंशम्
c. A1.सार्धात्सौर; B.साद्धासौर
d. A1.रचेः

Note 2. The following is the table of motions:

	1	2	3	4	5	6	7	Total
Degrees passed	– 16½° *asta.*	– 90½°	– 13°	– 120° *vakra*	– 91°	– 12½°	– 16½° *asta*	– 360°
Given days	18	98	14	113	98	13	19	373
Correct days	18	98	14	113	98	13½	18½	373

Note 3. The supplementary verses end abruptly without the usual verses giving details about the author, his parentage, date of writing etc.

Note 4. The colophon is simply "The star-planets of the *Pauliśa siddhānta* ends." But after this is found details about the scribe, his lineage, his time of writing, viz. 1673 Vikrama Saṃvat, and 1538 Śaka, equal to 1616 AD, and the purpose of his copying the work, ('for his own reading and helping others', i.e., other astronomers).

[इति पञ्चसिद्धान्तिकायाम् अष्टादशेऽध्याये
प्रक्षेपभागः समाप्तः] ||

Col. A1.B.D. पौलिशसिद्धान्ते (B3 न्तो) ताराग्रहाः (B adds एवम् |
C. इति पौलिशसिद्धान्ते ताराग्रहा नामाष्टदशोऽध्यायः

Post-Colophonic statements:

A1. इत्याचार्य-वराहमिहिरकृता पंचसिद्धांतिका समाप्ता संवत् १६७३ वर्षे शाके १५३८ प्रवर्तमाने द्वितीयाश्विनशुदि २ बुधे अद्येह स्तंभतीर्थे वास्तव्यं | पंडित-श्रीपीतांवर[:] तत्सूनुः श्री-श्रीरंग[:], तत्पुत्रः पंडित नाना । तत्तनयो पंडितगोविन्दः । तस्यात्मजेन शंकरेणेयं पंचसिद्धांतिका लिखिता । आत्मपढ (ठ)नार्थं तथा [परो]पकृतये च । शुभं भवतु । ।

B1.2.3. इत्याचार्यवराहमि[हि]रकृतायां
(B3. om. यां) पञ्चसिद्धान्तिका समाम्ता ।
(B3. संवत् १९२८ शाके १७९३ प्रवर्तमाने
माघशुक्ला २ शुक्रे | ज्योतिर्विदूत्तमरामदुर्लभरामेण
लिखिता || अमदावाद-निवासिना मुंबाई-
बन्दरमध्ये इंद पुस्तकं लिखितं || श्री ||
C. इति वराहमिहिराचार्यकृता पञ्चसिद्धान्तिका समाप्ता ।
D. इत्याचार्यवराहमिहिरकृता पंचसिद्धान्तिका समाप्ता ||

Thus ends Chapter XVIII 61-81: A Spurious Supplement entitled 'Computation of the Star Planets in Brief', to the Pañcasiddhāntikā of Varāhamihira

APPENDIX I
INDEX OF VERSES

APPENDIX II

INDEX OF PAÑCASIDDHĀNTIKĀ VERSES QUOTED BY LATER ASTRONOMERS

1. Makkibhaṭṭa's Com. on the *Siddhāntaśekhara* of Śrīpati : *PS* XIII.36; XV.17-20 (5 verses)
2. Nīlakaṇṭha Somayāji in his *Jyotirmīmamsā* : *PS* I.3, 4; XV.20 (3 verses)
3. Nīlakaṇṭha Somayāji in his *Bhāṣya* on the *Āryabhaṭīya* : *PS* III.21; XIII.1, 10; XV.20 (4 verses)

   Nīlakaṇṭha quotes two more verses from the *Pañcasiddhāntikā*, which, however are not to be found in the present edition of the work :

   See Nīlakaṇṭha on *ABh* IV.10 :

अत एवोक्तं वराहमिहिरेण पञ्चसिद्धान्ताख्ये करणे कर्तरिकाध्याये —

संख्या तु तेषां चिरजीविदृष्टा संवादहीना यदि यत्नभाजः ।
यंत्रैर्मयोक्तैः खगचारसूक्ष्मैस्तंत्रं विना सिद्ध्यन्ति खेचराणाम् ॥

Again, तदुक्तं कर्तरिकाध्याये —
यत्नतः प्रतिनिवृत्तिकालतः सौम्यतश्च विदितं यदन्तरम् ।
भास्करस्य दलितं यदेव हि क्रान्तिमाहुरधिकं पुरातनाः ॥

4. Parameśvara's Com. on the *Āryabhaṭīya* :
   PS XIII.12 (1 verse)
5. Pṛthūdakasvāmin's Com. on the *Khaṇḍakhādyaka* of Brahmagupta :
   PS. XIII.2-3, 5-6, 9, 12, 27, 35 (8 verses)
6. Sūryadevayajvan's Com. on the *Āryabhaṭīya* : XIII.1, 3, 36.
7. Utpala's Com. on the *Bṛhatsamhitā* of Varāhamihira :
   PS. I.1, 8-10, 16-22; II.13; III.1, 10, 21, 25; IV.20-23, 27-28, 30-33, 35-36, 38, 41-44; 48-49; V.1-10; VI.9-10, 15; VIII.1, 9-18; IX.1; XII.1-3; XIII.1-34, 39-42; XIV.33, 39-40; XV.15, 18-29; XVII.4-5 (117 verses)

APPENDIX III

BHŪTASAṄKHYĀ (OBJECT NUMERALS)
Used in the Pañcasiddhāntikā

akṣa	5	caraṇa	4	randhra	9
akṣi	2	jala	4	ravi	12
agni	3	jaladhi	4	rasa	6
aṅka	9	jina	24	rāma	3
atijagatī	13	tanu	8	rudra	11
adri	7	tithi	15	rūpa	1
anala	3	tīkṣṇāṁśu	12	lavaṇoda	4
abdhi	4	darśa	2	vasu	8
amara	33	dahana	3	vahni	3
ambara	0	dik	10	viyat	0
arka	12	dinanātha	12	viśva	13
arṇava	4	divapa	12	viṣaya	5
artha	5	divākara	12	veda	4
aśva	7	dhṛti	18	vyoman	0
aśvi	2	nakha	20	śara	5
ākāśa	0	nayana	2	śaśāṅka	1
āśā	10	naraka	40	śaśi	1
ina	12	nāga	7	śikhin	3
indu	1	pakṣa	2	śiva	11
indriya	5	bāṇa	5	śītakara	1
īśvara	11	bindu	0	śītaraśmi	1
utkṛti	26	bhava	11	śītāmśu	1
ṛtu	6	bhāskara	12	śūnya	0
kara	2	bhū	1	samudra	4
ku	1	maṇḍala	12	sāgara	4
kṛta	4	manu	14	svara	7
kṛti	20	mahī	1	svargeśa	11
kha	0	muni	7	himāṁśu	1
gagana	0	mūrcchana	21	hutabhuj	3
guṇa	3	yama	2	hutāśa	3
ghana	4	yamala	2	hutāśana	3
candra	1	yuga	4	hotṛ	3

APPENDIX IV

INDEX OF PLACES, PERSONS AND TEXTS
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APPENDIX V

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APPENDIX VI
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